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THE SCIENTIFIC MONTHLY

JULY, 1916

THE ORIGIN AND EVOLUTION OF LIFE UPON THE EARTH[1]

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LECTURE I. PART I

Introduction

We may introduce this great subject by putting to ourselves four leading questions: first, is life something new; second, is life evolution the same as stellar evolution; third, is there evidence that similar physico-chemical laws prevail in life and in lifeless evolution; fourth, are life forms the result of law or of chance?

First: does the origin of life[2] represent the beginning of something new in the cosmos, or does it represent the continuation and evolution of forms of matter and energy already found in the earth, in the sun, and in the other stars? This is the first question which occurs to us, and it is one which has not yet been answered. The more traditional opinion is that something new entered this and possibly other planets with the appearance of life; this is also involved in all the older and newer hypotheses which group around the idea of vitalism or the existence of specific, distinctive and adaptive energies in living matter. The more modern scientific opinion is that life arose from a recombination of forces preexisting in the cosmos. To hold to this answer, that life does not represent the entrance either of a new form of matter or of a new series of laws but is simply another step in the general evolutionary process, is certainly consistent with the development of me-

[1] Fourth course of lectures on the William Ellery Hale Foundation, National Academy of Sciences, delivered at the meeting of the academy at Washington, on April 17 and 19, 1916. The author is greatly indebted for many notes and suggestions in physics and chemistry to his colleagues in the National Academy and Columbia University, especially to M. I. Pupin, F. W. Clarke, G. F. Becker and W. J. Gies.

[2] In order to consider this problem from a fresh, unbiased, and original point of view the author has purposely refrained from reading the recent treatises of Shafer, Moore and others on the origin of life. In the chemical section the author is, however, indebted to the very suggestive work of Henderson entitled "The Fitness of the Environment."

chanics, physics and chemistry since the time of Newton and of evolutionary thought since Lamarck and Darwin.

Second: the second question relates to the exact significance of the term *evolution* when applied to lifeless and to living matter. Is the development of life evolutionary in the same sense or is it essentially different from that of the inorganic world? Let us critically examine this question by comparing the evolution of life with what is known of the evolution of matter, of the evolution of the stars, of the formation of the earth; in brief, of the comparative anatomy and physiology of the universe as developed in the preceding lectures of this course by Rutherford,[3] Campbell,[4] and Chamberlin;[5] of the possible evolution of the chemical elements themselves from simpler forms, in passing from primitive nebulæ through the hotter stars to the planets, as first pointed out by Clarke[6] in 1873, and by Lockyer in 1874.

Do we find a correspondence between the orderly development of the stars and the orderly development of life? Do we observe in life a continuation of processes which in general have given us a picture of the universe slowly cooling off and running down; or, after hundreds of millions of years of more or less monotonous repetition of purely physicochemical and mechanical reaction, do we find that electrons, atoms, and molecules break forth into new forms and manifestations of energy which appear to be "creative," conveying to our eyes at least the impression of incessant genesis of new combinations of matter, of energy, of form, of function, of character?

To our senses it seems as if the latter view were the correct one, as if something new had been breathed into the aging dust, as if the first appearance of life on this planet marked an actual reversal of the previous order of things. Certainly the cosmic processes cease to run down and begin to build up, abandoning old forms and constructing new ones. Through these activities within matter in the living state the dying earth, itself a mere cinder from the sun, develops new chemical compounds; the chemical elements of the ocean are enriched from new sources of supply, as additional amounts of chemical compounds, produced by organisms from the soil or by elements in the earth that were not previously dissolved, are liberated by life processes and ultimately carried out to sea; the very composition of the rocks is changed; a new life crust begins to cover the earth and to spread over the bottom of the sea. Thus our old inorganic planet is reorganized, and we see in living matter a reversal of the melancholy conclusion reached by Campbell[7] that

[3] Rutherford, Sir Ernest, 1914.
[4] Campbell, William Wallace, 1914.
[5] Chamberlin Thomas Chrowder, 1916.
[6] Clarke, F. W., 1873, p. 323.
[7] Campbell, William Wallace, 1915, p. 209.

Everything in nature is growing older and changing in condition; slowly or rapidly, depending upon circumstances; the meteorological elements and gravitation are tearing down the high places of the earth; the eroded materials are transported to the bottoms of valleys, lakes and seas; and these results beget further consequences.

Thus, in answer to our second question, it certainly appears that *living matter does not follow the old evolutionary order* but represents a new assemblage of energies and new types of action, reaction, and interaction—to use the terms of Newton—between those chemical elements which are as old as the cosmos itself, unless they prove to represent, as Clarke, Lockyer, and Rutherford have suggested, an evolution from still simpler elements.

Third, is there a continuation of the same physico-chemical laws? Yes, so far as we observe, the process is still *evolutionary rather than creative,* because all these new characters and forms invariably arise out of new combinations of preexisting matter and appear to broadly conform to the laws of thermodynamics, and especially to Newton's third law. According to the interpretation by Pupin of this third law of Newton, *action* and *reaction* refer to what is going on between material parts in actual contact, whereas *interaction* refers to what is going on between two material parts which are connected with each other by other parts. Action and reaction are simultaneous, whereas interaction refers to an action and reaction which are not simultaneous. For example, when one pulls at a line the horse feels it a little later than the moment at which the line is pulled; there is interaction between the hand and the horse's mouth, the line being the interconnecting part.

In this lecture I shall attempt to show that since in their *simple* forms living processes are known to be physico-chemical and are more or less clearly interpretable in terms of action, reaction and interaction, we are compelled to believe that *complex* forms will also prove to be interpretable in the same terms.

If we affirm that the entire trend of our observation is in the direction of the physico-chemical rather than of the vitalistic hypotheses this is very far from affirming that the explanation of life is purely materialistic or that any present physico-chemical explanation is either final or satisfying to our reason. Chemists and biological chemists have very much more to discover. May there not be in the assemblage of cosmic chemical elements necessary to life, which we shall distinguish as the *"life elements,"* some *known* element which thus far has not betrayed itself in chemical analysis? This is not impossible, because a known element like radium, for example, might well be wrapped up in living matter but as yet undetected, owing to its suffusion or presence in excessively small quantities or to its possession of qualities that have escaped notice. Or, again, an *unknown* chemical element, to which the

hypothetical term *bion* might be given, may lie awaiting discovery within this complex of known elements. Or an unknown source of energy may be active here. Or, as is far more probable from our present state of knowledge, unknown principles of action, reaction and interaction may await discovery: such principles are indeed adumbrated in the as yet partially explored activities of the catalytic agents in living chemical compounds.

In answer to our first main question, to which we now return, we may express as our own opinion, based upon the logical application of uniformitarian evolutionary principles, that when life appeared some energies preexisting in the cosmos were brought into relation with the elements or forces already existing. In other words, since every advance thus far in the quest as to the nature of life has been in the direction of a physico-chemical rather than a vitalistic explanation, from the time when Lavoisier (1743–1794) put the life of plants on a solar-chemical basis, logically following the same direction, we believe that the last step into the unknown—one which possibly may never be taken by man—will also be physico-chemical in all its measurable and observable properties, and that the origin of life, as well as its development, will ultimately prove to be a true evolution within the preexisting cosmos.

None the less, such evolution, we repeat with emphasis, is not like that of the chemical elements or of the stars; the evolutionary process now takes an entirely new and different direction. Although it arises through combinations of preexisting energies it is essentially constructive and creative; it is continually giving birth to an infinite variety of new forms and functions which never appeared in the universe before. While this creative power is something new derived from the old, it presents the first of the numerous contrasts between the living and the lifeless world.

We are now prepared for the fourth of our leading questions. It having been determined that the evolution of non-living matter follows certain physical laws and that the living world conforms to many if not to all of these laws the final question which arises is: does the living world also conform to law in its most important aspect, namely, that of fitness or adaptation, or does law emerge from chance?

Let us first make clear the distinction between law and chance. On this a physicist (M. I. Pupin) observes:

> In physics, when distinguishing between law and chance, we speak of coordinated phenomena like planetary motions, and of *non-coordinated* phenomena like the motion of individual molecules in a large number of molecules. In regard to such motion, chance or probability or so-called statistical modes of procedure guide the reasoning. Again, *radiation* is a statistical or non-coordinated mode of procedure, and since it is closely related to the growth of plants (the simplest forms of life) why is not life in its constituent elements a statistical or chance procedure? May not life-forms and life itself be differentiated just like the motion of radiating atoms and observable forms of radiation?

Although the motions giving rise to radiation are haphazard, the resulting forms of radiation which we observe are definite and beautifully arranged as if they proceeded from perfectly coordinated and not from perfectly haphazard motions.

It is obvious that the answer to these questions put by a physicist may be reached in biology through observation.

Campbell has described the orderly development of the stars and Chamberlin the orderly development of the earth: is there also an orderly development of life? Are life forms, like celestial forms, the result of law or are they the result of chance? This is perhaps the very oldest biologic question that has entered the human mind, and it is one on which the widest difference of opinion exists even to-day.

Chance has been the opinion held by a great line of philosophers from Democritus and Empedocles to Darwin, and including Poulton, de Vries, Bateson, and many others of our own day: chance is the very essence of the Darwinian selection hypothesis of evolution. William James[8] and many other eminent philosophers have adopted the "chance" view as if it had been actually demonstrated, instead of being, as it is, one of the string of hypotheses upon which Darwin hung his theory of the origin of adaptations and of species. To quote the opinion of a recent writer:

> And why not? Nature has always preferred to work by the hit or miss methods of chance. In biological evolution millions of variations have been produced that one useful one might occur.[9]

I have long maintained that this opinion is a biological dogma[10] which has gained credence through constant reiteration, for I do not know that it has ever been demonstrated through the actual observation of any evolutionary series.

Law has been the opinion of another school of natural philosophers, headed by Aristotle, the opponent of Democritus and Empedocles. This opinion has fewer philosophical and scientific adherents; yet Eucken,[11] following Schopenhauer, has recently expressed it as follows:

> From the very beginning the predominant philosophical tendency has been against the idea that all the forms we see around us have come into existence solely through an accumulation of accidental individual variations, by the mere blind concurrence of these variations and their actual survival, without the operation of any inner law. Natural science, too, has more and more demonstrated its inadequacy.

Unlike our first question as to whether the principle of life introduced something new in the cosmos, a question which is still in the stage of pure speculation, this fourth question of law versus chance in the

[8] James, William, 1902, pp. 437–439.

[9] Davies, G. R., 1916, p. 583.

[10] Biology like theology has its dogmas. Leaders have their disciples and blind followers. All great truths, like Darwin's law of selection, acquire a momentum which sustains half-truths and pure dogmas.

[11] Eucken, Rudolf, 1912, p. 257.

evolution of life is no longer a matter of opinion, but of direct observation. So far as law is concerned life forms are like those of the stars: their origin and development as revealed through paleontology go to prove that Aristotle was essentially right when he said that "Nature produces those things which, being continually moved by a certain principle contained in themselves, arrive at a certain end."[12] What this internal moving principle is remains to be discovered. We may first exclude the possibility that it acts either through supernatural or teleologic interposition; and although its visible results are in a high degree purposeful we may exclude as unscientific the vitalistic theory of an *enteleche* or any other form of distinct internal perfecting agency. The fact that the principle underlying many complex forms of adaptation is still unknown, unconceived, and perhaps inconceivable, does not inhibit our opinion that adaptation will prove to be a continuation of the previous cosmic order. Since certain forms of adaptation which were formerly mysterious can now be explained without the assumption of an *enteleche,* it follows that all forms of adaptation may some day be explained in the same way.

But if we reject the vitalistic hypotheses we are driven back to the necessity of further physico-chemical analysis and research.

We shall discover that the first striking phenomenon in life is the *extraordinary complexity of the actions, reactions and interactions of forces which gradually evolves.* This complex of four interrelated sets of physico-chemical energies which I have previously adumbrated[13] as the most fundamental biologic law may now be restated as follows:

Actions, Reactions and Interactions of	*Selection*
1. The Cosmic Environment (physico-chemical energies). 2. The Individual Development (biochemical energies of the developing individual). 3. The Chromatin (biochemical energies of the heredity substance). 4. The Life Environment (biochemical energies of other individuals).	Competition with other individuals (factors of Natural Selection and Elimination, leading to survival or extinction).

This law I shall put forth in different aspects as the central thought of these lectures, stating at the outset that it involves an unknown prin-

[12] Osborn, H. F., 1894, p. 56.

[13] In several previous statements and definitions of this law I have termed it the law of the four inseparable factors of evolution, including environment (organic and inorganic), individual development, heredity (the chromatin) and selection. I now perceive that selection should not be included with the other factors because it is no sense coordinate. The causes of the origin and evolution of life must lie entirely within the physico-chemical and biochemical cycle. Osborn, H. F.

ciple, namely, the nature of the action, reaction, and interaction of the cosmic and life environment and individual developmental energies with the energies of the heredity substance. The nature of this unknown principle,[14] which is at present almost entirely beyond the realm of observation and experiment, will, however, be made clearer through the development of our main subject, the *origin and evolution of life upon the earth so far as it has been observed up to the present time or so far as it can be legitimately inferred from actual observation.*

The Earth as a Developing Environment

In general, our narrative will follow the "uniformitarian" method of interpretation first presented in 1788 by Hutton,[15] who may be termed the Newton of geology, and elaborated in 1830 by Lyell,[16] the master of Charles Darwin. In the spirit of the preparatory work of the great pioneers in geology, such as Hutton, Scrope and Lyell, and of the history of the evolution of the working mechanism of organic evolution, as developed by Darwin and Wallace,[17] our inferences as to past processes are founded upon the observation of present processes. The uniformitarian doctrine is this: present continuity implies the improbability of past catastrophism and violence of change, either in the inorganic or in the organic world.

We shall consider in order, first, the evolution of the inorganic environment necessary to life; second, the advent of life, what is known of its nature and in regard to the time and the form in which it probably originated; and third, the evolution of life, its orderly development, the differentiation and adaptation of the various life forms; while throughout we shall trace the operation of our fundamental biologic law, which involves the action, reaction and interaction of environment and individual development with the forces of heredity.

PRIMORDIAL ENVIRONMENT—THE LIFELESS EARTH

Let us first look at the cosmic environment, the inorganic world before the entrance of life. Since 1825, when Cuvier[18] published his famous "Discours sur les Revolutions de la Surface du Globe," the past history of the earth, of its waters, of the atmosphere, and of the sun—the four great complexes of inorganic environment—has been written with some approach to precision. Astronomy, physics, chemistry, geology and paleontology have each followed along their respective lines of observation, resulting in some concordance and much discordance of opinion and theory. In general we shall find that opinion founded

[14] See Osborn, H. F., 1909, 1912, 1, 1912, 2.

[15] Hutton, James, 1795.

[16] Lyell, Charles, 1830.

[17] Judd, John W., 1910.

[18] Cuvier, Baron Georges L. C. F. D., 1825.

upon life data has not agreed with opinion founded upon physical or chemical data. Discord has arisen especially in connection with the age of the earth and the stability of the earth's surface. In our review of these matters we may glance at opinions of all kinds, whatever their source; but our main narrative of the chemical origin and history of life on the earth will be followed by observations on living matter as it is revealed in paleontology and as it exists to-day, and not on hypotheses and speculations upon preexisting states.

The formation of the earth's surface is a prelude to our considering the first stage of the environment of life. According to the planetesimal theory, as set forth by Chamberlin[19] in the preceding lectures, the earth, instead of consisting of a primitive molten globe as postulated by the old nebular hypothesis originated in a nebulous knot of solid matter as a nucleus of growth which was fed by the infall or accretion of scattered nebulous matter (planetesimals) coming within the sphere of control of this knot. The temperature of these accretions to the early earth could scarcely have been high, and the mode of addition of these planetesimals one by one explains the very heterogeneous matter and differentiated specific gravity of the continents and oceanic basins. The present form of the earth's surface is the result of the combined action of the lithosphere, hydrosphere, and atmosphere. Liquefaction of the rocks occurred locally and occasionally as the result of heat generated by increased pressure and by radioactivity; but the planetesimal hypothesis assumes that the elastic rigid condition of the earth, as at present, prevailed—at least in its outer half—throughout the history of its growth from the small original nebular knot to its present proportions and caused the permanence of its continents and of its oceanic basins. We are thus brought to conditions that are fundamental to the evolution of life on the earth. According to the opinion of Chamberlin cited by Pirsson and Schuchert,[20] life on the earth may have been possible when it attained the present size of Mars.

According to Becker,[21] who follows the traditional theory of a primitive molten globe, the earth first presented a nearly smooth, equipotential surface, determined not by its mineral composition, but by its density. As the surface cooled down a temperature was reached at which the waters of the gaseous envelope united with the superficial rocks and led to an aqueo-igneous state. After further cooling the second and final consolidation followed, dating the origin of the granites and granitary rocks. The areas which cooled most rapidly and best conducted heat formed shallow oceanic basins, whereas the areas of poor conductivity which cooled more slowly stood out as low continents. The internal heat of the cooling globe still continues to do its work, and the

19 Chamberlin, Thomas Chrowder, 1916.

20 Pirsson, Louis V., and Schuchert, Charles, 1915, p. 535.

21 Becker, George F., letter of October 15, 1915.

cyclic history of its surface is completed by the erosion of rocks, by the accumulation of sediments, and by the following subsidence of the areas loaded down by these sediments. It appears that the internal heat engine is far more active in the slowly cooling continental areas than in the rapidly cooling areas underlying the oceans, as manifested in the continuous outflows of igneous rocks, which, especially in the early history of the earth—at or before the time when life appeared—covered the greater part of the earth's surface. The ocean beds, being less subject to the work of the internal heat engine, have always been relatively plane; except near the shores, no erosion has taken place.

The Age of the Earth

The age of the earth as a solid body affords our first instance of the very wide discordance between physical and biological opinion. Among the chief physical computations are those of Kelvin, Sir George Darwin, and King and Barus.[22] In 1879 Sir George Darwin allowed 56 million years as a probable lapse of time since the earth parted company with the moon, and this birthtime of the moon was naturally long prior to that stage when the earth, as a cool crusted body, became the environment of living matter. Far more elastic than this estimate was that of Lord Kelvin, who, in 1862, placed the age of the earth as a cooling body between 20 and 400 million years, with a probability of 98 million years. Later, in 1897, accepting the conclusions of King and Barus calculated from data for the period of tidal stability, Kelvin placed the age limit between 20 and 40 million years, a conclusion very unwelcome to evolutionists.

As early as 1859 Charles Darwin led the biologists in demanding an enormous period of time for the processes of evolution, being the first to point out that the high degree of evolution and specialization seen in the invertebrate fossils at the very base of the Paleozoic was in itself a proof that pre-Paleozoic evolution occupied a period as long as or even longer than the post-Paleozoic. In 1869 Huxley renewed this demand for an enormous stretch of pre-Cambrian time; and as recently as 1896 Poulton[23] found that 400 million years, the greater limit of Kelvin's original estimate, was none too much. Later physical computations greatly exceeded this biological demand, for in 1908 Rutherford[24] estimated the time required for the accumulation of the radium content of a uranium mineral found in the Glastonbury granitic gneiss of the Early Cambrian as no less than 500 million years.

This estimate of the age of the Early Cambrian is eighteen times as great as that attained by Walcott[25] in 1893 from his purely geologic

[22] Becker, George F., 1910, p. 5.
[23] Poulton, Edward B., 1896, p. 808.
[24] Rutherford, Sir Ernest, 1906, p. 189.
[25] Walcott, Charles D., 1893, p. 675.

computation of the time rates of deposition and maximum thickness of strata from the base of the Cambrian upwards; but recent advances in our knowledge of the radioactive elements preclude the possibility of any trustworthy determination of the age of the elements through the methods suggested by Joly and Rutherford.

We thus return to the estimates based upon the time required for the deposition of stratified rocks as by far the most reliable, especially for our quest of the beginning of the life period, because erosion and sedimentation imply conditions of the earth, of the water, and of the atmosphere more or less comparable to those under which life is known to exist. These geologic estimates, which begin with that of John Phillips in 1860, may be tabulated as follows:

Time required for the Processes of Past Deposition and of Sedimentation at Rates Similar to Those observed at the Present Day[26]

1860.	John Phillips	38– 96 million years.
1890.	De Lapparent	67– 90 million years.
1893.	Walcott (27,640,000 years since the base of the Cambrian Paleozoic; 17,5000,000 years or upwards for the pre-Paleozoic.)	55– 70 million years.
1899.	Geikie (Minimum 100 million years; maximum—slowest known rates of deposition—400 million years.)	100–400 million years.
1909.	Sollas (The larger estimate of 80 million years on the theory that pre-Paleozoic sediments took as much time as those from the base of the Cambrian upwards, allowing for gaps in the stratigraphic column.)	34– 80 million years

These estimates give a maximum of 64 miles as the total amount of sedimentation, which is equivalent to a layer 2,300 feet thick over the entire face of the earth.[27] From these purely geologic data the time ratio of the entire life period is now calculated in terms of millions of years, assuming the approximate reliability of the geologic time scale. The actual amount of rock weathered and deposited was probably far greater than that which has been preserved.

In general these estimates are broadly concordant with those reached by an entirely different method, namely, the amount of sodium chloride (common salt) contained in the ocean, to understand which we must take another glance at the primordial earth.

The lifeless primordial earth can best be imagined by looking at the lifeless surface of the moon, featured by volcanic action with little erosion or sedimentation. The surface of the earth, then, was chiefly

[26] Becker, George F., 1910, pp. 2, 3, 5.
[27] Clarke, F. W., 1916, p. 30.

spread with the granitic batholiths and the more superficial volcanic outpourings. There were volcanic ashes; there were gravels, sands, and micas derived from the granites; there were clays from the dissolution of granitic feldspars; there were loam mixtures of clay and sand; there was gypsum from mineral springs. Bare rocks and soils were inhospitable ingredients for any but the most rudimentary forms of life, such as were adapted to feed directly upon the chemical elements and their simplest compounds or to transform their energy without the friendly aid of sunshine. The only forms of life to-day which can exist in such an inhospitable environment as that of the lifeless earth are certain of the simplest bacteria.

It is interesting to note that in the period when the sun's heat was partly shut off by vapors the *early volcanic condition of the earth's surface* may have supplied life with fundamentally important chemical elements as well as with the heat-energy of the waters or of the soil. Volcanic emanations contain[28] free hydrogen, both oxides of carbon, and frequently hydrocarbons such as methane (CH_4) and ammonium chloride: the last compound is often very abundant. Volcanic waters sometimes contain ammonium (NH_4) salts, from which life may have derived its first nitrogen supply. In the Devil's Inkpot, Yellowstone Park, ammonium sulphate forms 83 per cent. of the dissolved saline matter: it is also the principal constituent of the mother liquor of the boric fumaroles of Tuscany, after the boric acid has crystallized out. A hot spring on the margin of Clear Lake, California, contains 107.76 grains per gallon of ammonium bicarbonate.

There were absent in the primordial earth the greater part of the fine sediments and detrital material which now cover three-fourths of the earth's surface, and from which a large part of the sodium content has been leached. The original surface of the earth was thus composed of igneous rocks to the exclusion of all others,[29] the essential constituents of these rocks being the lime-soda feldspars from which the sodium of the ocean has since been leached. Waters issuing from such rocks are, as a rule, *relatively* richer in silica than waters issuing from modern sedimentary areas. They thus furnished a favorable environment for the development of such low organisms (or their ancestors) as the existing diatoms, radiolarians, and sponges. These have skeletons composed of hydrated silica, mineralogically of opal.

The decomposition and therefore the erosion of the massive rocks was slower then than at present for none of the life agencies of bacteria, of algæ, of lichens, and of the higher plants, which are now at work on granites and volcanic rocks in all the humid portions of the earth, had yet appeared. On the other hand, much larger areas of these rocks were exposed than at present. In brief, to imagine the primal

[28] Clarke, F. W., 1916, Chap. VIII., also pp. 197, 199, 243, 244.

[29] Becker, George F., 1910, p. 12.

earth we must deduct all those portions of mineral deposits which as they exist to-day are mainly of organic origin, such as the organic carbonates and phosphates of lime,[30] the carbonaceous shales as well as the carbonaceous limestones, the graphites derived from carbon, the silicates derived from diatoms, the iron deposits made by bacteria, the humus of the soil containing organic acids, the soil derived from rocks which are broken up by bacteria, and even the ooze from the ocean floor, both calcareous and siliceous, formed from the shells of foraminifera and the skeletons of diatoms. Thus, before the appearance of bacteria, of algæ, of foraminifera, and of the lower plants and lowly invertebrates, the surface of the earth was totally different from what it is at present; and thus the present chemical composition of terrestrial matter, of the sea, and of the air, as indicated by Table I, is by no means the same as its primordial composition sixty million years ago.

TABLE I

AVERAGE DISTRIBUTION OF THE ELEMENTS IN EARTH, AIR AND WATER AT THE PRESENT TIME[31]

	Lithosphere, 93 Per Cent.	Hydrosphere, 7 Per Cent.	Atmosphere	Average, Including Atmosphere
Oxygen	47.17	85.79	20.8 (variable to some extent)	49.85
Silicon	28.00	......	....	26.03
Aluminum	7.84	......	....	7.28
Iron	4.44	......	....	4.12
Calcium	3.42	.05	....	3.18
Magnesium	2.27	.14	....	2.11
Sodium	2.43	1.14	....	2.33
Potassium	2.49	.04		2.33
Hydrogen	.23	10.67	variable	.97
Titanium	.44	......	....	.41
Carbon	.19	.002	variable	.19
Chlorine	.06	2.07	....	.40
Bromine	....	.008	....	
Phosphorus	.11	......	....	.10
Sulphur	.11	.09	....	.10
Barium	.09	......	....	.09
Manganese	.08	......	....	.08
Strontium	.03	......	....	.03
Nitrogen	....	......	78.0 (variable to some extent)	.03
Fluorine	.10	......	....	.10
All other elements	.50	......	....	.47

[30] It seems improbable that organisms originally began to use carbon or phosphorus in *elementary* form: carbonates and phosphates were probably available at the very beginning and resulted from oxidations of decompositions.—W. J. Gies.

Phosphate of lime, apatite, is an almost ubiquitous component of igneous rocks, but in very small amount. In more than a thousand analyses of such rocks, the average percentage of P_2O_5 is 0.25 per cent.—F. W. Clarke.

[31] Clarke, F. W., 1916, p. 34.

In Table I all the "life elements" which enter more or less freely into organic compounds are indicated by italics, showing that life has taken up and made use of practically all the chemical elements of frequent occurrence with the exception of aluminum, barium and strontium, which are extremely rare in life compounds, and of titanium, which thus far has not been found in any. But even these elements appear in artificial organic compounds, showing combining capacity without biological "inclination" thereto. In the life compounds, as in the lithosphere and hydrosphere, it is noteworthy that the elements of least atomic weight predominate over the heavier elements.

PRIMORDIAL ENVIRONMENT—THE LIFELESS WATER

According to the theory of Laplace the waters originated in the primordial atmosphere; according to the planetesimal theory of Chamberlin[32] and Moulton[33] the greater volume has been gradually added from the interior of the earth through the vaporous discharges of hot springs. As Suess observes,

> The body of the earth has given forth its ocean.

From the beginning of Archeozoic time, namely, for eighty million years, we have little biologic or geologic evidence as to the stability of the earth. From the beginning of the Paleozoic, namely, for a period of thirty million years, the earth has been in a condition of such stability that the oceanic tides and tidal currents were similar to those of the present day; for the early strata are full of such evidences as ripple marks, beach footprints, and other proofs of regularly recurrent tides.[35]

As in the case of the earth, the chemistry of the seas is a matter of inference, *i. e.*, of subtraction. The relatively simple chemical content of the primordial seas must be inferred by deducting the mineral and organic products which have been sweeping into the ocean from the earth during the last eighty to ninety million years; and also by deducting those that have been precipitated as a result of chemical reactions, calcium chloride reacting with sodium phosphate, for example, to yield precipitated calcium phosphate and dissolved sodium chloride.[36] The present waters of the ocean are rich in salts which have been derived by solution from the rocks of the continents.

Thus we reach our first conclusion, namely: it is probable that life originated on the continents, either in the moist crevices of rocks or soils, in the fresh waters of continental pools, or in the slightly saline waters of the bordering primordial seas.

As long ago as 1715 Edmund Halley suggested that the amount of

[32] Chamberlin, Thomas Chrowder, 1916 .
[33] Moulton, F. R., 1912, p. 244.
[35] Becker, George F., 1910, p. 18.
[36] W. J. Gies.

salt in the ocean might afford a means of computing its age. Assuming a primitive fresh-water sea, Becker[37] in 1915 estimated the age of the ocean as between 50 and 70 million years, probably closer to the upper limit. The accumulation of sodium was probably more rapid in the early geologic periods than at the present time, because the greater part of the earth's surface was covered with the granitic and igneous rocks which have since been largely covered or replaced by sedimentary rocks, a diminution causing the sodium content from the earth to be constantly decreasing.[38] This is on the assumption that the primitive ocean had no continents in its basins and that the continental areas were not much greater than at the present time, namely, 20.6 per cent. to 25 per cent. of the surface of the globe.

Age of the Ocean Calculated from its Sodium Content[39]

1876.	T. Mellard Reade	
1899.	J. Joly	80– 90 million years.
1900.	J. Joly	90–100 million years.
1909.	Sollas	80–150 million years.
1910.	Becker	50– 70 million years.
1911.	F. W. Clarke and Becker	94,712,000 years.
1915.	Becker	60–100 million years.
1916.	Clarke	somewhat less than 100 million years.

From the mean of the foregoing computations it is inferred that the age of the ocean since the earth assumed its present form is somewhat less than 100 million years. The 63 million tons of sodium which the sea has received yearly by solution from the rocks has been continually uniting with its equivalent of chlorine to form the salt (NaCl) of the existing seas.[40] So with the entire present content of the sea, its sulphates as well as its chlorides of sodium and of magnesium, its potassium, its calcium as well as those rare chemical elements which occasionally enter into the life compounds, such as copper, fluorine, boron, barium—all these earth-derived elements were much rarer in the primordial seas than at the present time. Yet from the first the air in sea-water was much richer in oxygen than the atmosphere.[41] The primal sea was also devoid of those nitrogen compounds which are chiefly derived from the earth through the agency of the nitrifying bacteria. Those who hold to the hypothesis of the *marine origin* of protoplasm fail to account for the necessary proportion of nitrogenous matter there to begin with.

37 Becker, George F., 1910, pp. 16, 17.

38 Becker, George F., 1915, p. 201; 1910, p. 12.

39 After Becker, George F., 1910, pp. 3–5; and Clarke, F. W., 1916, pp. 150, 152.

40 Becker, George F., 1910, pp. 7, 8, 10, 12.

41 Pirsson, Louis V., and Schuchert, Charles, 1915, p. 84.

When we consider that these "chemical life elements," so essential to living matter, were for a great period of time either absent or present in a highly dilute condition in the ocean, it appears that we must abandon the ancient Greek conception of the origin of life in the sea, and again reach the conclusion that the lowliest organisms originated either in moist earths or in those terrestrial waters which contained nitrogen. Nitrates occasionally arise from the union of nitrogen and oxygen in electrical discharges during thunderstorms and were presumably thus produced before life began. Such nitrogen compounds, so essential for the development of protoplasm, may have been specially *concentrated* in *pools of water* to degrees particularly *favorable* for the *origin of protoplasm.*[42]

From terrestrial waters or soils life may have gradually extended into the sea. It appears, too, that every great subsequent higher life phase—the bacterial phase, the chlorophyllic algal phase, the protozoan phase—was also primarily of fresh-water and secondarily of marine habitat. It is probable that the succession of marine forms was itself determined to some extent by adaptation to the increasing concentration of saline constituents in sea-water. That the invasion of the sea upon the continental areas occurred at a very early period is demonstrated by the extreme richness and profusion of marine life at the base of the Cambrian.

As compared with primordial sea-water which was relatively fresh and free from salts and from nitrogen existing sea-water is an ideal chemical medium for life. As a proof of the special adaptability of existing sea-water to present biochemical conditions, a very interesting comparison is that between the chemical composition of the chief body fluid of the highest animals, namely, the blood serum, and the chemical composition of sea-water, as given by Henderson.[43]

CHEMICAL COMPOSITION OF SEA-WATER AND OF BLOOD SERUM

"Life Elements"	In Sea-water	In Blood Serum
Sodium	30.59	39.0
Magnesium	3.79	0.4
Calcium	1.20	1.0
Potassium	1.11	2.7
Chlorine	55.27	45.0
SO_4	7.66	
CO_3	0.21	12.0
Bromine	0.19	
P_2O_5		0.4

That life originated in water (H_2O) there can be little doubt. The

[42] Suggested by Professor W. J. Gies.

[43] Henderson, Laurence J., 1908, II., p. 145.

fitness of water is maximal[44] both as a solvent in all the bodily fluids, and as a vehicle for most of the other chemical compounds. Further, since water itself is a solvent that fails to react with many substances (with nearly all biological substances) it serves also as a factor of biochemical stability. Water and the carbon dioxide of the atmosphere are the common source of every one of the complicated organic compounds and also the common end products of the materials yielding energy to the body. Proteins are made from supplies containing nitrogen material in addition.

In relation to Newton's law of action, reaction and interaction the most important property of water is its dielectric constant. Although itself only to a slight degree dissociated into ions it is the bearer of dissolved electrolytic substances and possesses a high power of electric conductivity, properties of great importance in the development of the electric energy of the molecules and atoms in ionization. Thus water is the very best medium of electric ionization in solution, and was probably essential to the mechanism of life from its very origin.[45]

Through all the electric changes of its contained solvents water itself remains very stable because the molecules of hydrogen and oxygen are not easily dissociated; their union in water contributes to the living organism a series of properties which are the prime conditions of all physiological and functional activity. The great surface tension of water as manifested in capillary action is of the highest importance to plant growth; it is also an important force acting within the formed colloids, the protoplasmic substance of life.

PRIMORDIAL ENVIRONMENT—THE ATMOSPHERE

It is significant that the simplest known living forms derive their "life elements" partly from the earth, partly from the water, and partly from the atmosphere. This was not improbably true also of the earliest living forms.

One of the mooted questions concerning the primordial atmosphere[46] is whether or no it contained free oxygen. The earliest forms of life were probably dependent on atmospheric oxygen, although certain existing bacterial organisms, known as "anærobic," are now capable of existing without it.

The primordial atmosphere was heavily charged with water vapor (H_2O) which has since been largely condensed by cooling. In the early period of the earth's history volcanoes[47] were also pouring into the atmosphere much greater amounts of carbon dioxide (CO_2) than at the

[44] These notes upon water are chiefly from the very suggestive treatise "The Fitness of the Environment," by Henderson, Lawrence J., 1913.

[45] Henderson, Lawrence J., 1913, p. 256.

[46] Becker, George F., letter of October 15, 1915.

[47] Henderson, Lawrence J., 1913, p. 134.

present time. At present the amount of carbon dioxide in the atmosphere averages about three parts in 10,000, but there is little doubt that the primordial atmosphere was richer in this compound which next to water and nitrogen is by far the most important both in the origin and in the development of living matter. The atmospheric carbon dioxide is at present continually being reduced by the absorption of carbon in living plants and the release of free oxygen; it is also washed out of the air by rains. On the other hand, the respiration of animals is continually returning it to the air. The large amount of aqueous vapor and of carbon dioxide in the primordial atmosphere served to form an atmospheric blanket which inhibited the radiation of solar heat from the earth's surface and also prevented excessive changes of temperature. Thus there was on the primal earth a greater regularity of the sun's heat supply, with more moisture, while the light supply from the sun was less intense and constant than at present. This is in general accord with the fact that the most primitive organisms surviving upon the earth to-day, the bacteria, are rather dependent upon heat than upon light for their energy. It is also possible that through the agency of thermal springs and the heat of volcanic regions primordial life forms may have derived their energy from the heat of the earth rather than from that of the sun.

The stable elements of the present atmosphere, for which alone estimates can be given, are essentially as follows:[48]

	By Weight	By Volume
Oxygen	23.024	20.941
Nitrogen	75.539	78.122
Argon	1.437	.937
	100.000	100.000

Since carbon is a less essential element[49] in the life-processes of the simplest bacteria, we can not agree with Henderson[50] that carbon dioxide was coordinate with water as a primary compound in the origin of life. It probably was subsequently utilized in the chlorophyllic stage of plant evolution.

Atmospheric carbon dioxide (CO_2) which averages about three parts in every 10,000, and water (H_2O) is always present in varying amounts; beside argon, the rare gases helium, xenon, neon, and krypton are present in traces. None of the rare gases which have been discovered in the atmosphere, such as helium, argon, xenon, neon, krypton, and niton—the latter a radium emanation—are at present known to have any relation to the life processes. Carbon dioxide exists in the atmos-

[48] Clarke, F. W., letter of March 7, 1916.
[49] Jordan, Edwin O., 1908, p. 66.
[50] Henderson, Lawrence J., 1913, pp. 138, 139.

phere as an inexhaustible reservoir of carbon, only slightly depleted by the drafts made upon it by the action of chlorophyllic plants or by its solution in the waters of the continents and oceans. Soluble in water and thus equally mobile, of high absorption coefficient, and of universal occurrence, it constituted a reservoir of potential energy for the development of plants and animals. Carbon dioxide in water forms carbonic acid, one of the few instances of biological decomposition of water. This compound is so unstable that it has never been obtained. Carbon dioxide is now produced not only within the atmosphere but also by the action of certain anærobic bacteria and molds without the presence of free oxygen, as, for example, through the catalytic action of zymase, the enzyme of yeast, which is soluble in water. Loeb[51] dwells upon the importance of the bicarbonates as regulators in the development of the marine organisms by keeping neutral the water and the solutions in which marine animals live. Similarly the life of fresh-water animals is also prolonged by the addition of bicarbonates.

Thus from the chlorophyllic stage onwards the compounds of carbon, hydrogen, and oxygen (C, H, O)[52] constitute a unique ensemble of fitness among all the possible chemical substances for the exchange of matter and energy both within the organism and between it and its environment. The "regulator" or "balancing" influence is exerted by the phosphates and upon the acidifying tendency of carbon dioxide. The carbon dioxide in respiration raises the hydrogen concentration of the blood. The phosphates restrain this tendency while the breathing apparatus, in response to stimulus from the respiratory center irritated by the hydrogen, throws out the excess of the latter.

[51] Loeb, Jacques, 1906, pp. 96, 97.

[52] Henderson, Lawrence J., 1913, pp. 71, 194, 195, 207, 231, 232.

(*To be continued*)

THE ANIMAL-BREEDING INDUSTRY

By Dr. RAYMOND PEARL

THE MAINE AGRICULTURAL EXPERIMENT STATION

ANIMAL-BREEDING as an industry lies at the foundation of animal husbandry, which in turn is a basic element of the art of agriculture. Before any of the domestic animals can be used to provide food or clothing for mankind, the animals themselves must be produced. It is the function of the art or craft of animal-breeding to *produce* the world's supply of domestic animals of all kinds.

An attribute of living organisms, which fundamentally differentiates them from non-living matter, is the faculty of self-reproduction. Certain cells of the body in all higher animals are able, under suitable conditions, to go through a process of development which has as its end result the production of a new individual of the race or species. Through these cells (known as reproductive cells, or gametes) the animal has the power of reproducing itself. A new and distinct individual existence is brought into the world. Nothing like this is known in the inorganic realm. The stone in the field is not capable, through any self-initiated or self-perpetuated activity, of causing the coming into existence of a new stone, essentially like itself in form, size, structure, chemical composition and every other quality. Only plants and animals—in other words, living things—can do this.

It is this fundamental attribute of self-reproduction which the art of animal-breeding makes use of for the benefit of mankind. The breeder attempts to direct and control the reproduction of certain species and varieties of animals which possess qualities that are of value. Thus the breeder of dairy cattle endeavors so to control and direct the reproduction of these animals that he shall be able to produce cows which will yield a large amount of milk. The beef-cattle breeder tries to produce animals which carry on their frames a large amount of meat of good edible quality. The sheep-breeder has for his object to bring about the plentiful reproduction of animals bearing a large amount of wool. And so on, always the breeder is trying to control, guide and direct a fundamental biological process (reproduction) in such way that the product may be most valuable to him in some direction, either utilitarian, æsthetic or other. The more complete this control is, and the more definitely it is directed towards a particular desired end, the greater is the success of the breeder.

Man's needs or fancies have led to the production of many and diverse breeds of the domestic animals. In every civilized country special breeds and sub-breeds or varieties have been developed to meet the particular conditions prevailing there. In the number of such specialized and diversified races of animals, all of which must have come originally from a very small number of unspecialized ancestral forms, is perhaps to be found the most striking measure of the degree to which man has developed and extended his control over the natural processes of reproduction. Some idea of the extent to which this differentiation and specialization of animals for particular ends has been carried may be gained from Table I. This table shows the number of different breeds and varieties of farm live stock which are found in the British Isles.[1] Some are local varieties, but still distinct. All these are essentially native British breeds. Other countries, especially the older ones, show in greater or less degree the same conditions. They have developed breeds of live stock to suit their own special needs and fancies.

TABLE I

Showing the Numbers of Different Breeds of British Live Stock

Kind of Stock	Number of Distinct British Breeds and Varieties
Horses	17
Beef cattle	13
Dairy cattle	7[2]
Sheep	34
Swine	8

It is evident from this table that the skill of the English breeder has well justified the reputation it has created for the British Isles as one of the chief sources of the pure-bred live stock of the world.

To produce the world's supply of domestic animals, which we have seen to be the business of the animal breeder, is a task of great magnitude. Resort must be had to statistics[3] if any just conception is to be

[1] This table is compiled from "British Breeds of Live Stock," London (Board of Agriculture and Fisheries), 1910.

[2] Counting the Dairy Shorthorn as a distinct variety.

[3] The raw data on which the following statistical discussion is based are taken from the official returns of the U. S. Department of Agriculture, as published in the Yearbooks. The writer is, of course, responsible for the treatment of these figures here developed and for the deductions made.

The fact that the statistics here used are three years old in no wise invalidates the conclusions. Essentially the same conclusions would be reached from a survey of the stock-breeding industry in any normal year. Of course just at the present time industrial conditions of all sorts, including stock-breeding, are upset by war conditions. On that account, indeed, it is altogether probable that the facts as here presented give a much more nearly *normal* picture of the industry than would statistics for the years 1914 or 1915.

formed of the extent and importance of this breeding industry. We shall confine our attention to the United States, remembering that except in certain rather restricted lines, the animal-breeding industry in this country has as yet had no special or intensive development.

The following table shows the number of living domestic animals of various kinds which were on farms in the United States on January 1, 1912, together with their estimated farm value. The figures take no account of the vast numbers of horses, for example, which are not on farms.

TABLE II

NUMBER AND VALUE OF FARM LIVE STOCK IN THE UNITED STATES ON JANUARY 1, 1912

Kind of Stock	Number	Value
Horses	20,509,000	$2,172,694,000
Mules	4,362,000	544,359,000
Milch cattle	20,699,000	815,414,000
Other cattle (chiefly beef)	37,260,000	790,064,000
Sheep	52,362,000	181,170,000
Swine	65,412,000	523,328,000
Total	200,602,000	$5,027,029,000

Each one of these two hundred million animals was produced by a definite breeding operation. Somewhere somebody, with more or less care and thought as to the result, mated together two animals to produce each one of the individuals or litters which lumped together give this enormous total. The mere statement of such large figures conveys little impression to the mind. Let us try by comparison to see what the figures really mean. If all the live stock on farms in the United States on January 1, 1912, had been sold at a price such as to realize the estimated farm value in cash, and then the money so obtained had been equally divided, each individual man, woman and child in the country would have received as his share from this transaction $54.66. Furthermore the farm value of live stock represented an amount sufficient to pay the whole principal of the public debt of the United States (equal to $2,906,750,548.66 on October 1, 1913) nearly twice over.

This same sum of money would support the common schools of the United States for more than 12 years, assuming the same rate of school expenses as obtained in 1908–09. The mules or the swine each alone, if converted into cash, would pay all the common school expenses for more than a year, the cattle for four years, and the horses more than five years. The sheep of the country on January 1, 1912, were worth more than one and a half times as much as the entire property (lands, buildings, equipment, etc.) of all the colleges of agriculture and mechanic arts in the United States in 1910, the last year for which figures were available when this was written.

The figures given do not tell the whole story of the magnitude of the animal-breeding industry of the country. They deal only with the live stock actually on the farm. Besides this are the exports to be reckoned with. Table III. gives the facts regarding exports.

TABLE III

NUMBER AND VALUE OF LIVE STOCK EXPORTED FROM THE UNITED STATES DURING THE YEAR ENDING JUNE 30, 1911

Kind of Stock	Number	Value
Horses	25,145	$ 3,845,253
Mules	6,585	1,070,051
Cattle	150,100	13,163,920
Sheep	121,491	636,272
Swine	8,551	74,032
Total	311,872	$18,789,528

Over against the exports are to be set the imports. Animals are imported into the United States for purposes falling into two general classes. On the one hand, are the imports, mainly from European countries, of superior animals to be used as breeding stock. The ultimate object of such importation is the improvement of the live-stock of the country. On the other hand, there are some importations of animals for purposes of slaughter and utilization in other ways than breeding. The live-stock imports of each of these classes for the fiscal year 1910–11 are given in Table IV.

TABLE IV

NUMBER AND VALUE OF LIVE STOCK IMPORTED INTO THE UNITED STATES DURING THE YEAR ENDING JUNE 30, 1911

Kind of Stock	Why Imported	Number	Value
Horses	For breeding purposes	6,331	$2,055,418
"	" other "	3,262	636,656
Cattle	" breeding "	2,441	362,220
"	" other "	180,482	2,590,857
Sheep	" breeding "	5,341	116,277
"	" other "	48,114	261,348
Total	....	245,971	$6,022,776

From the figures given in the preceding tables it is possible to make some calculations to show average individual values. These are of interest because they furnish some indications of the cash value which rewards attention and care devoted to the breeding of animals. Let us first consider the average values of the different kinds of live stock on the farm. These figures will furnish a base with which comparison may be made. They measure in a crude way, but still a real one, the

stage of development or progress which the live stock breeding industry of the country has attained. Table V. gives the figures, calculated from the data given in Table II. above.

TABLE V

AVERAGE VALUES OF LIVE STOCK ON THE FARM

Kind of Stock	Average Value of the Individual
Horses	$105.94
Mules	124.80
Milch cows	39.39
Other cattle	21.20
Sheep	3.47
Swine	8.00

It is to be expected that animals chosen for export will be on the average of somewhat better quality than those left on the farm. A part go out of the country for breeding purposes, and these will have a powerful effect in raising the average value of exported stock. In accordance with expectation, the average values for exported stock are seen in Table VI. to be in every case somewhat greater than those for farm stock. The relative amount of this increase, shown as the percentage which the difference in values is of the farm value, is given for each class of stock in a third column of the table.

TABLE VI

AVERAGE VALUES OF LIVE STOCK EXPORTED

Kind of Stock	Average Value of Individual	Percentage Increase in Average Value of Exported Over Farm Live Stock
Horses	$152.92	44.3
Mules	162.50	30.2
Cattle	37.70	216.7[4]
Sheep	5.24	51.4
Swine	8.66	8.2

While the relative increases of value seen here are respectable, considered by themselves, they are insignificant in comparison with those exhibited in the valuation of animals *imported* for breeding purposes. The figures for the latter are shown in Table VII., which is calculated in the same way as Table VI.

TABLE VII

AVERAGE VALUES OF LIVE STOCK IMPORTED FOR BREEDING PURPOSES

Kind of Stock	Average Value of Individual	Percentage Increase in Average Value of Imported Over Farm Live Stock
Horses	$324.66	206.5
Cattle	148.39	435.8
Sheep	21.77	529.2

[4] Calculated on the basis of weighted mean of the two classes of cattle distinguished in Table V.

Taking these figures at their face value, for the moment, they indicate that the average horse imported into the United States for breeding purposes is worth twice as much as the average horse on an American farm. The average cow or bull imported is worth four and a third times as much as the average cow or bull on the farm; while the average imported sheep is more than five and a quarter times as valuable as the home product on the farm.

These figures furnish an impressive object lesson as to the value of paying attention to the breeding of live stock. Fundamentally the enhanced valuation of the imported animals rests on the fact that they are better bred than the average farm stock here. Their qualities all approach the ideal more closely. But they have been brought to that condition by the practise of skilful, well-planned and carefully executed breeding.

The statistical data so far presented regarding the breeding industry have been drawn from official returns and cover the country as a whole. They suffer from the defects of such statistics. While they show the general relations in a substantially correct way, they tend to reduce to a minimum differences of all kinds. In the case of the last comparison made, the indicated difference in average valuation between farm and live stock and that imported for breeding purposes is probably distinctly less than the true difference. A better comparison, and one which not only shows what careful breeding means to the farmer and to the nation as a source of wealth, but also shows that the foreigner has no monopoly on the production of fine breeding stock, is between average farm values and the prices realized at auction dispersal sales of pedigreed stock in this country. Let us examine a few figures of this kind.

Table VIII[5] gives the average sale price of pedigreed beef cattle in all sales held in this country during the six years preceding 1913.

The increase of these prices over the $21.00 of the farm cattle is obvious. The same considerations apply to other kinds of stock. At a Guernsey cattle sale held in Oconomowoc, Wisconsin, March 20, 1912, 69 head were sold at an average price of $377.26. Mr. H. E. Browning of Hersman, Ill., sold 41 Duroc-Jersey swine "of his own breeding" on December 19, 1912, at an average price of $173 per head. The contrast of this price with the $8.00 average on the farm is sufficiently striking.

The live-stock breeding industry of the world rests on a foundation of pure-bred pedigreed stock. The constant aim of the breeder from the earliest time has been to produce differentiated types particularly adapted to his locality, conditions and needs. Having once found or developed such a type, the breeder wishes to keep it. This he can only

[5] Compiled by the *Breeders' Gazette* and published in the issue of January 1, 1913.

TABLE VIII

AVERAGE PRICES REALIZED AT AUCTION SALES OF PEDIGREED BEEF CATTLE

Name of Breed	1912			1911			1910		
	No. of Sales	No. Sold	Av. Price	No. of Sales	No. Sold	Av. Price	No. of Sales	No. Sold	Av. Price
Short-horn	45	1,882	$177.40	53	2,258	$162.50	49	1,999	$187.50
Hereford	15	957	180.40	19	1,203	160.50	20	1,214	146.20
Aberdeen-Angus	12	627	138.95	13	723	143.60	19	995	167.35
Galloway	*...	...	......	*...	...	......	1	67	83.30
Polled Durham	2	83	132.85	1	42	140.60	3	74	115.00
Red Poll	1	30	107.25	*...	...	......	1	41	185.00

Name of Breed	1909			1908			1907		
	No. of Sales	No. Sold	Av. Price	No. of Sales	No. Sold	Av. Price	No. of Sales	No. Sold	Av. Price
Short-horn	78	3,308	$159.00	59	2,689	$146.50	84	3,608	$160.15
Hereford	25	1,398	127.05	15	936	116.15	29	1,358	123.70
Aberdeen-Angus	18	935	189.00	18	955	165.10	18	1,119	134.75
Galloway	2	69	128.05	3	136	84.50	3	123	139.05
Polled Durham	2	79	129.45	6	244	124.50	3	106	130.35
Red Poll	3	35	97.80	1	3	50.00	3	97	83.00

* No public sales reported.

do if it "breeds true." It obviously could not be expected to breed true if at frequent intervals it were crossed with other types. The breeding of individuals all of the same general type, and belonging to a few family lines, could be safely left to the individual breeder in the earlier days of the industry. With the wider development of the industry this was no longer possible. It became necessary to have an official registration of pedigrees, which should be beyond any chance of manipulation by the breeder. In this way one wishing to purchase an animal of a particular breed would have definite and objective evidence that the individual was, in fact, of the breed it was supposed to be.

Out of this need have grown the systems of pedigree registration in herd-books, stud-books and the like. In certain countries at the present time these registry records have an enhanced official status, because they are under governmental control and supervision. In the United States the control of live-stock registration is in some degree supervised by the Bureau of Animal Industry of the federal Department of Agriculture, particularly so far as concerns the registration of imported animals.

Under this system of pedigree registration an animal is regarded as "pure bred" if both its sire and dam are recorded in one of the officially recognized books of registration. No further biological criterion is demanded. A strict biological interpretation of the words "pure bred" would exclude many animals which are registered under the present system. The biological conception of hereditary "purity" has become much refined in recent years, and it now appears that the term "pure

bred" should apply in a strict sense to characters rather than to individuals.

The statistical data given in the foregoing discussion are by no means complete, but they serve sufficiently well the present purpose, which is simply to give some conception of the magnitude of the live stock breeding industry and its importance as a source of wealth to the nation. No account has been taken of other than farm live stock, and such obviously represents only a part of the animals which somebody has to breed to supply the needs of the people. Further nothing has been said about poultry, which represents an important industry in itself. Altogether, however, the following statement by Heape,[7] in concluding a review of the value of the breeding industry in England, is as well justified by conditions in this country, as in the country for which it was written. He says:

> All I have attempted is, to give such a broad idea of the number and value of live stock in the kingdom, as the careful consideration of evidence I have been able to obtain, permits. I have taken the utmost care to avoid exaggeration, and in this, at any rate, I have reason to think I have succeeded.
>
> When it is recollected that the Board of Agriculture returns are below, may be 10 per cent. or even more below the correct figures; when it is recollected what a large proportion of the people in the country, farmers, dealers, shopkeepers, farm-labourers, working men of various kinds, and gentlemen's servants, make their living in one way or another by means of stock; when it is recollected what a very large number of valuable animals there are in this country, as shown by a sale of yearlings at Newmarket, the prices obtained at the dispersal of a herd of Shorthorns or a flock of Southdowns, the value of a successful horse on the turf, of a good hunter, polo pony, pair of carriage-horses or cart-horses, of a couple of pointers, a spaniel, a bull-dog or lap-dog, etc., when such facts are borne in mind I do not think there can be found justification for objection to the final figures I have arrived at on the score of excess; and yet they show a total sum of nearly £450,000,000 invested in live stock in this country.
>
> When to this is added the capital necessary to provide both buildings to house the stock, land on which to grow their food, barns, machinery, vehicles, harness and attendance, the total becomes so gigantic that I am surely justified in asserting: We have here an industry of enormous importance to the country, and one which merits far more attention than has ever yet been accorded to it; an industry to which, it must be remembered, "Science has never yet been applied."

[7] Heape, W., "The Breeding Industry," Cambridge, 1906.

THE REVERSUS, A FISHING TALE OF CHRISTOPHER COLUMBUS

By Dr. C. R. Eastman

American Museum of Natural History

TRULY a remarkable fish story that which should require an analysis of the earliest sources of American history in order to attest its credibility. Nevertheless there lies buried among the contemporary narratives that have come down to us of the second voyage of Columbus, in 1494, a tale of fish and fishermen of such interest and novelty, and apparent truthfulness, as will repay attention on the part of present-day students of history and natural science.

The original narrator of the fishing incident about to be described appears to have been Columbus himself. Unfortunately, however, the log or journal kept by the great navigator during his second voyage is no longer extant; but we possess abridgments of it in what passes for the "Life of Columbus," by his son Ferdinand, and also in the "History of the Indies" which we owe to that man of revered memory, Bartolomé de las Casas.

There has also been preserved for us a letter written by a naturalist who accompanied Columbus during his second voyage, Dr. Diego Alvarez Chanca; and much information derived from personal intercourse with the admiral and the men under his command is embodied in the writings of Peter Martyr of Anghera, sometimes styled the "father of American history," and in the chronicles of Andrés Bernaldez, curate of Los Palacios, in Andalusia. It is of record that Columbus placed his journals and other papers in the hands of Bernaldez, whose guest he was in 1496. Thirteen chapters of the curate's book are devoted to an account of Columbus and his discoveries. These, then, are the original sources to be consulted in regard to the happenings which took place during the memorable second voyage to the West Indies.

From the writings that have just been mentioned we learn that the Spaniards came upon a party of native fishermen off the coast of Cuba who were engaged in the capture of marine turtles, the means employed by them for that purpose being wholly unlike anything ever seen or heard of in Europe. In a word, it consisted in the use of a sucking-fish, known to naturalists as the *Remora,* which, after having been caught and tethered (so to speak) by means of a cord attached to its body, was allowed to fasten itself by its sucking disc to another fish or turtle, whereupon both were drawn in. Historians have frequently repeated the narrative, but only a single naturalist, Alexander von Humboldt,

appears to have inquired into the premises at all carefully. It may therefore be instructive for us to compare two or three of the different versions that are contained in the original sources, after which we may be better able to interpret the actual facts.

First of all it will be of interest to traverse in imagination with Columbus the route by which he steered his caravels amid the verdant, perfume-laden isles that dot the sea near Cuba, as he sailed westward in the month of May, 1494, with the project not only of finding a new route to India, but of actually sailing round the world. This we know from what Ferdinand Columbus tells us in a passage undoubtedly derived from his father's journal of the second voyage, "that if he had had abundance of provisions he would not have returned to Spain except by way of the East."[1] Through the irony of fate the Admiral was obliged to turn back from near that point where the fishing scene was witnessed, when two or three days more sailing would have proved to him the insular character of Cuba, and might have led to the immediate discovery of Yucatan, or Mexico.

We shall let Ferdinand tell us in his own language, which we may be sure follows very closely his father's journal, of what took place as the first European vessels to navigate along the southern coast of Cuba came upon the Queen's Gardens. The English rendering here given is found in the second volume of "Churchill's Voyages" (p. 536), and reads thus:

> On Saturday, the 3d of May, the Admiral resolved to sail over from Cuba to Jamaica, that he might not leave it behind without knowing whether the report of such plenty of gold they heard there was in it, prov'd true; and the wind being fair, and he almost half way over, discovered it on Sunday. Upon Monday he came to an anchor, and thought it the beautifullest island of any he had yet seen in the Indies, and such multitudes of people in great and small canoes came abroad that it was astonishing. . . .
>
> The wind being somewhat contrary, the Admiral could not make so much way as he wished, till on Tuesday the 13th of May he resolved to stand for Cuba, to keep along its coast, designing not to return till he had sailed 5 or 600 leagues, and were satisfied whether it were an island or continent. . . .
>
> The nearer they sailed to Cuba, the higher and pleasanter the little islands appeared which were all over that sea, and it being a matter of difficulty and to no purpose to give every one of them a name, the Admiral called them all in general *Jardin de la Reina*, the Queen's Garden. . . . In these islands they saw crows and cranes like those of Spain, the sea-crows [gulls], and infinite numbers of little birds that sung sweetly, and the air was as sweet as if they had been among roses, and the finest perfumes in the world; yet the danger was very great, there being such abundance of channels, that much time was spent in finding the way out.
>
> In one of these channels they spy'd a canoe of Indian fishermen, who very quietly, without the least concern, awaited the boat which was making towards them, and being come near, made a sign to them in it to attend till they had done fishing.

[1] "Hist." p. 166.

Their manner of fishing was so strange and new to our men, that they were willing to comply with them. It was thus: they had ty'd some small fishes they call *Reverso* by the tail, which run themselves against other fish, and with a certain roughness they have from the head to the middle of the back they stick fast to the next fish they meet; and when the Indians perceive it drawing their line, they hand them both in together. And it was a tortoise our men saw so taken by those fishermen, that fish [the Reverso] clinging about the neck of it, where they generally fasten, being by that means safe from the other fish biting them; and we have seen them fasten upon vast sharks.

When the Indians in the canoe had taken their tortoise, and two other fishes they had before, they presently came very friendly to the boat, to know what our men would have, and by their directions went along aboard the ships, where the Admiral treated them very courteously. . . .

Proceeding thence, and bearing up closer to Cuba, they saw tortoises of a vast bigness, and in such numbers that they covered the sea. At break of day they saw such a cloud of sea-crows that they darkened the sun, coming from the seaward to the island, where they all lighted; besides them, abundance of pigeons, and birds of other sorts were seen, and the next day there came such swarms of butterflies that they darkened the air, and lasted till night, when the rain carried them away. . . .

In the brief description which is here given of the captive "fisherman-fish," or Reverso, we are told that it has a peculiar asperity along the back. Ferdinand's "Historie" has not come down to us in its original Spanish form, but is known only in translations, the earliest being that of Ulloa, in Italian. It may be that the English rendering to the effect that the Reverso was armed with "a certain roughness from the head to the middle of the back" does not accurately convey the sense of the original. At all events a slightly different description is given in the French version, which reads: "certain petit poisson qui porte de piquants crochus se relevant à contresens de son corps," etc. The latter characterization agrees better with the porcupine-fish, or Diodon, than the Remora, and both are included under the term of "Reversus" by the "fathers" of ichthyology, one being called the spinous, and the other the anguilliform variety.

In the histories of Las Casas and Herrera we read practically the same account of fishing with the Reversus as that given by Ferdinand Columbus. Of similar purport, also, but closely agreeing in literary style with the writings of the famous discoverer, is the account of the same fishing scene in Queen's Gardens which we find in the chronicles of Andrés Bernaldez.[1] We now present this passage in English form.

Chapter CXXVI

Of a great number of Islands which were Discovered

The Admiral set sail [from Jamaica] with his three caravels, and sailed 24 leagues towards the west, as far as the gulf Buen Tiempo. . . . On Whitsunday, 1494, they stopped at a place which was uninhabited—but not from the inclemency of the sky, or the barrenness of the soil—in the midst of a large grove of palm-trees, which seemed to reach from the sea-shore to the very heavens.

[1] "Hist. Reyes Catól.," Cap. 126.

. . . Here they all rested themselves upon the grass about these fountains, enjoying the charming fragrance of the flowers, and the melody of the song of birds, so many and so sweet, and the shade of the palm trees, so tall and so beautiful, that the whole was a wonder. . . . As the number of islands in this region was so great that he could not give to each a separate name, the Admiral called them all by the common name of the Queen's Gardens.

On the day following, the Admiral being very desirous to fall in with some natives with whom he might parley, there came a canoe to hunt for fish:—for they call it hunting, and they hunt for one fish with others of a particular kind. They have certain fishes which they hold by a line fastened to their tails, and which are like conger-eels in shape, and have a large mouth [*i. e.*, head] completely covered with suckers, like the octopus. They are very fierce, like our ferrets, and when they are thrown into the water they fly to fasten themselves upon whatsoever fish they may espy, and sooner die than let go their hold till they are drawn out of the water.

The hunting fish is very light, and as soon as he has taken hold, the Indians draw him by the long cord attached to his body, and in this manner they take a fish each time on drawing both to the surface of the water.

As these hunters were at a distance from the caravel, the Admiral sent his boats to them with armed men, contriving it so that they should not escape to the land. As the boats came up to them, these hunters called out to the men in mildest manner and as unconcernedly as if they had known them all their lives, to hold off, because one of the fishes had fastened upon the under side of a large turtle, and they must wait till they had got it into the canoe. This our men did, and afterwards they took the canoe, and those in it, together with four turtles, each of which was three cubits in length, and brought them to the ships of the Admiral; and there they gave some account of these islands, and of their cacique who was close at hand, and had sent them to hunt. They asked the Admiral to go on shore, and they would make for him a great feast and would give him all of the four turtles they had caught.

Clearly the description just given refers to the "eel-like Reversus" or Remora, and so far as the description goes it is a more dependable sketch than the portrayal which Peter Martyr has preserved for us in the pioneer collection of voyages,[8] published in 1504, and "De Rebus Oceanis" of 1511. The following narrative is taken from the fifteenth chapter of the "Libretto":

Continuing [along the coast of Cuba] they found further onward some fishermen in certain of their boats of wood excavated like *zopoli*, who were fishing. In this manner they had a fish of a form unknown to us, which has the body of an eel and larger: and upon the head it has a certain very tender skin which appears like a large purse. And this fish they drag, tied with a cord to the edge of the boat, because it can not endure a breath of air. And when they see any large fish or reptile, they loosen the noose and this fish at once darts like an arrow at the fish or other creature, throwing over them this skin which he has upon his head; which he holds so firmly that they are not able to escape, and he does not leave them if they are not taken from the water; but as soon as he feels the air he leaves his prey and the fishermen quickly seize it. And in the presence of our people they took four large turtles which they gave our people for a very delicate food.

[8] "Libretto de Tutta la Navigatione de Re de Spagna, de le Isole et Terreni Novamente Trovati." The text for this libretto was written some time previous to the summer of 1501, and was reproduced in the fourth book of the "Paesi Novamente Retrovati," first published at Vicenza in 1507.

The entertaining writer whom we have just quoted gives a more elaborate account of this same incident, and manner of fishing with the Reversus, in the work by which he is best known, the "Decades of the Ocean," first published in 1511; but it is not necessary to follow these later modifications.

The next writer to treat of the same theme, with considerable enlargement of detail, is the well-known historian Oviedo, whose "Sumario" was published in 1516, and larger work on the "History of the Indies" in 1535. Oviedo gives a lively account of the intelligence of the "fisherman-fish," which he asserts was reared in captivity by the natives and trained to catch prey "as huntsmen or falconers use hounds or hawks in their game." But in his description of the fish itself Oviedo has strangely confused the characters of the sucking-fish with those of Diodon. Thus, he speaks of the "reverso" as being covered with imbricating scales, upon which are "certain prickles very sharp and strong, whereby he fastens himself to what fish he pleaseth; and these prickly scales he hath on most parts of his body."[4] Ferdinand Columbus also, as we have seen, describes the reverso as armed with backwardly pointing spines, which of course suggests Diodon. And it is Diodon that we find figured alongside of the Remora in sixteenth to eighteenth century ichthyological writings as if it were a second variety or "species" of the so-called "Reversus." Its curious antics on being hooked were first described by Père Du Tertre in 1657.[5]

One may inquire whence the name Reversus was derived; and the answer would seem to be that it is cognate in meaning with the classic name of the fish Remora, or Echeneis, which signifies "holding back."[6] That the Remora, or "ship-holder," actually impeded the progress of sailing vessels is an extremely ancient legend, which has survived to modern times.[7] The subject is illustrated in Greek and Roman ceramic art, and occurs repeatedly in classic as well as medieval literature. In the accompanying figure we have reproduced one of the earliest woodcuts in printed books depicting the Remora in the act of retarding a vessel; it is from the 1536 edition of the "Hortus Sanitatis." The illustration here given does not differ materially from that found in the *editio princeps* of this curious work, printed in 1479. The fishing scenes contained in the first editions respectively of the "Hortus Sanitatis" and "Dialouges of Ceatures Moralyzed" are probably the first of their kind to be introduced into printed books. Copies are also shown of Gesner's (1558) and Aldrovandi's (1638) representations of

[4] This sentence is taken from "Purchas his Pilgrimes," III., p. 994.

[5] "Hist. Antilles," II., p. 209.

[6] The Cuban naturalist Felipe Poey suggests that the name Reverso was applied by the Spaniards to the fish "parce que l'animal parait tourné *au rebours*, quand il se fixe." ("Hist. Nat. de Cuba," II., p. 249). Peter Martyr offers a like explanation.

[7] See Dr. Günther's article on the Remora, in *Ann. Mag. Nat. Hist.* for 1860, Ser. 3, Vol. 5, p. 386.

the Remora as a hunting-fish, and of Diodon appearing under the same guise.

How it happened that in the time of Columbus Diodon should become confused with Remora in the alleged capacity of a hunting-fish is a puzzling question. We may conjecture, however, that the porcupine-fish was among the number of specimens which, as Columbus tells

FIG. 1. EARLIEST KNOWN FIGURE INTENDED TO REPRESENT THE REMORA (*Echeneis*) OR "SHIP-STAYER," From the second edition of J. von Cube's "Hortus Sanitatis." Leipzig, 1490.

us in the journal of his first voyage, he ordered to be salted and carried back to Spain.[8] One of these was thought by Cuvier to have been the

[8] In the journal of the first voyage, part of the entry for Friday, November 16, 1492, reads as follows: "The sailors also fished with nets, and, among many others, caught a fish which was exactly like a pig, not like a tunny, but all covered with a very hard skin, without a soft place except the tail and the eyes, and an opening on the under side for voiding the superfluities. It was ordered to be salted, to bring home for the sovereigns to see."

Still earlier, under date of October 16, Columbus wrote this entry, which may be compared in style with the language quoted from Bernaldez in describing the Queen's Gardens:

"Here the fish are so unlike ours that it is wonderful. Some are of the shape of dories, and of the finest colors in the world, blue, yellow, red and other tints,

Figura hac desumpta est ex tabula quadam descriptionis orbis terrarum.

FIG. 2. FISHING WITH THE REMORA, AS RELATED BY COLUMBUS. From Conrad Gesner's "Historiæ Animalium," Lib. IV, 1558.

trunk-fish; and another may well have been Diodon, these two forms being especially suitable for preservation, and as a matter of fact were well represented in the primitive museums of the time.[9] And being exhibited at the Court of Spain, one can conceive that the legend of the "reverso" became associated with this fish, and also the tale of its being trained for the capture of other fish.

So much for the original sources of the "Reversus" fishing incident: let us now consider its credibility. Humboldt, a century ago, gave full credence to the narrative, as related by Ferdinand Columbus, and conjectured that the species of sucking-fish employed by the natives at Queen's Gardens was probably *Echeneis naucrates*.[10] He also recalled that the French naturalist Commerson had noted among the inhabitants of Mozambique a similar use of the Remora for the capture of marine turtles; and cited Dampier (erroneously, however) and Captain Rogers to the same effect. From still another source, namely, the voyage of the Swedish traveler Andrew Sparrman,[11] we learn of African natives near the Cape of Good Hope making use of the Remora in identical manner for the capture of marine turtles.

all painted in various ways, and the colors are so bright that there is not a man who would not be astonished, and would not take great delight in seeing them. There are also whales. I saw no beasts in the island [of Cuba] of any kind, except parrots and lizards."

[9] See G. Brown Goode on "American Trunk-fishes," *Proc. U. S. Nat. Museum*, 1879, pp. 261–283.

[10] "Recueil d'Observ. Zool.," II., p. 192.

[11] "Voyage to the Cape of Good Hope." London, 1785. Paris, 1787. (French ed., II., p. 431.)

In order that the reader may judge of the similarity of the accounts of African and West Indian fishing with the Remora, we present at this point an English rendering of Commerson's observations. The original is found in Lacépède's treatise on Fishes.

The Indian Remora, *Echeneis naucrates*, is very common about the coasts of Mozambique, where it is sometimes made use of for the following very singular manner of catching turtles. A ring is fastened round the tail of the fish, in such a manner as to prevent its escape, and a long cord fastened to the ring. When thus prepared, the fish is carried in a vessel of sea-water, and when the boatmen observe a turtle sleeping, as is the frequent habit of those animals, on the surface of the water, they approach as near as possible without disturbing it; and then throwing the Remora into the sea, and giving it the proper length of cord, it soon attaches itself to the under side of the sleeping turtle, which is thus easily drawn to the boat by the fishermen.[12]

The distinguished ichthyologist, Dr. Albert Günther, in referring to the accounts of Commerson and others, expresses doubt as to their genuineness, and states that they appear to have originated rather from an experiment than from regular practise. Dr. D. S. Jordan, also, doubts whether the large *Echeneis naucrates*, which he has studied in Cuba, was ever practically used in the manner described. We are permitted to quote the views of this authority as communicated in a personal letter. This reads in part:

FIG. 3. AN ILLUSTRATION FROM OGILBY'S AMERICA (1671) REPRESENTING THE SCENE DESCRIBED BY COLUMBUS IN FISHING WITH THE "REVERSUS" NEAR CUBA.

[12] Shaw's "General Zoology," 1808, II., p. 209.

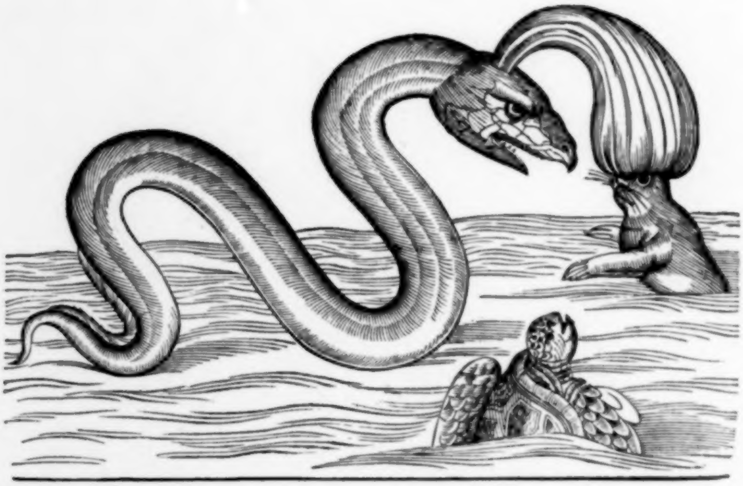

FIG. 4. THE REMORA, OR EEL-LIKE VARIETY OF THE REVERSUS. From Aldrovandis' "De Piscibus," 1628.

The minute the shark to which *E. naucrates* has fastened itself is drawn out of the water, it loosens its hold, and gets out of the way in a hurry. I do not think it could be trusted to fetch in a turtle, or any other large fish; and I never knew it to cling to any small fish. The smaller sucking-fish, *Remora remora*, clings tight. I have drawn up big sharks in the mid-Pacific with the Remora attached, and it wouldn't let go. Dr. Gilbert tells me that in Japan he has taken them off from sharks and kept them in the aquarium. They clung tight to the glass, not leaving it to swallow small fish until these came very close. But Remora, rarely exceeding 16 inches in length, could never be used in fishing and the big *Echeneis* doesn't "sit tight." The name "Reversus" seems to me to come from the fact that these fish, having black bellies, seem to be wrong-side up. Often when attached to other fish they are in that position.

On the other hand, some modern instances of fishing with the Remora have been reported, as for instance, the account published by Mr. Holmwood, a British consul in Madagascar, published in the *Proceedings of the London Zoological Society* for 1884, page 411. Dr. E. W. Gudger, who has been studying the Remora, has collected a number of apparently trustworthy observations; and Dr. Townsend, director of the New York Aquarium, has made practical tests of the adhesive power of these fishes. Dr. Townsend writes:

We used to catch a good many while I was cruising with the *Albatross*. When these fishes were thrown into tubes or buckets of sea water they took hold at once with their sucking discs and could not be detached without using considerable force. I have tied a stout cord around the tail of a two-foot Remora which attached itself to the inside of a two-gallon galvanized pail half-filled with water, and was then able to lift the pail, fish and water without the fish's grip giving way an inch. The pail and water weighed twenty-one pounds. The largest Remora in the aquarium is thirty-two inches long, and its cephalic disc is seven inches long and three inches wide. I have no doubt that with this fish attached to a good-sized sea turtle you could hand in the latter without difficulty.

FIG. 5. DIODON, OR SO-CALLED "SPINOUS VARIETY OF THE REVERSUS." From Aldrovandis' "De Piscibus," 1638.

Another genus of sucking fish larger and more powerful than either the Remora or *Echeneis* is *Remiligia,* which apparently has the habit of attaching itself regularly to the bodies of Cetacea, and for that reason has come infrequently to the attention of ichthyologists.[13]

If we come now to form an opinion as to the credibility of the original narrative of the great discoverer, weighing it in the light of modern information, there would appear to be no sufficient reason for rejecting it as improbable or the creation of a florid imagination.

[13] See a note on *Remora australis* by John T. Nichols, in *Bull. Amer. Mus. Nat. Hist.*, XXXII., 1913, p. 182.

THE VARIABLE DESERT

By Dr. J. ARTHUR HARRIS

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SINCE 1903, the Desert Botanical Laboratory of the Carnegie Institution of Washington has served as a base for field excursions for many scientific men—not botanists merely, but geographers, geologists, physiographers, climatologists, zoologists and anthropologists. These men have come into personal contact with the southwestern deserts and have looked upon inert and living features with eyes trained for the most diverse sorts of details. Many of them have set forth in popular as well as in technical terms their impressions of these vast and scientifically fascinating regions of our national territory. To add another to the excellent descriptions of the region available from the pens of Coville, McGee, Hornaday, Huntington, Lloyd, Spaulding and MacDougal would be quite superfluous were it not for the fact that none of these men have, as it seems to me, emphasized in a few paragraphs the one essential feature of our southwestern deserts, which makes them possibly the best naturally equipped experimental laboratories which have been placed within the reach of American students of living things.

The striking characteristic of this whole region is heterogeneity, variability, contrast—whichever one may wish to call it. This is manifest in every fundamental element of the environmental substratum—geographic, physiographic, climatic, edaphic and biologic. Its consequences are discernible in every feature of the biological superstructure—floristic, morphologic, physiographic and genetic.

To the average reader, the word desert calls up the mental picture of a region of bare rocks and dry wind-swept sand, inhospitable to any but the toughest plant and intolerable to any but the hardiest animal. Such a desert presents to the imagination a landscape of the direst monotony—a landscape exactly the opposite of that of our southwestern deserts, which are filled with diversity and interest.

Geologically, the deserts of the general region of Tucson consist of a number of rugged mountain groups, varying greatly in age and composition, with their long detrital slopes and the alluvial valley of the Santa Cruz.

Biologically, the topography of a region is generally a far more important factor than its composition. Within easy reach of the Desert Laboratory are three ranges of mountains with elevations of 9,000 feet or over. Thus within a few miles of the lowest point in the Santa Cruz

valley there is a rise of roughly 6,500 feet. This necessarily means great variety of topography.

The biological covering of so diversified a terrain would be highly differentiated even in a region of the earth's surface in which rainfall is ample in amount and uniform in distribution. Here, irregularity and violence of rainfall is superimposed upon irregularity of surface and plays its part as a powerful environmental factor.

Leaving Tucson by any of the chief highways, one finds himself at once in vast stretches of mesa or of rocky slopes, showing everywhere the most striking marks of water action. To find a xerophytic vegetation in a region where records of water action are so conspicuous is a great surprise to the novice; yet the one is really the logical consequence of the other.

The twelve inches, more or less, of annual rainfall are divided between a season of gentler winter showers and another of torrential summer rains. The former leave very little evidence of their occurrence on the landscape. The latter are often very heavy and their eroding power very great. In one of these, quite unusual, to be sure, five inches of water fell—an amount constituting about half the total precipitation of that year and nearly equal in amount to the total rainfall of the dryest of thirty-one years recorded for Tucson.

The rocky hillsides with only scattered vegetation turn all but a small percentage of the water of these summer cloudbursts into the rocky gulches or canyons, which pass it on to the broad sandy arroyas traversing the long bajadas, transforming both, for a short time, into raging torrents which record their depth by the drift, or even large stones, lodged in the branches of the scrubby trees which mark their courses, in some places many feet above the sandy or gravelly floor, where one fries his bacon and spreads his sleeping bag in the dry season. Past the bajada slopes, the water flows over the broad valleys. Often these are of indeterminate drainage—fine examples of sheet flood erosion. Thus the less precipitous mountain slopes show long ragged gashes cut through the superficial detrital layer to the solid rock beneath, while the fine adobe soil of the apparently flat valleys show here and there areas where the sheet waters have last evaporated, alkali or salt spots, where the drainage is inadequate or sharply carved gutters, where the flatness is only apparent and the gradient really sufficient to give the flowing water considerable cutting power.

With so large a proportion of the total precipitation coming with violence, immediately running off the surface of the steeper slopes and rapidly sinking into the deeper underlying layers in the valleys, physiographic evidence of water action and vegetational evidence of its absence are, in a region of intense heat, inevitable.

This division of the annual precipitation into two periods would

result in marked diversity in the water relations of the plant species, even if the entire amount sank uniformly into the soil. Besides this fundamental source of diversity, there are others.

The amount of water which may fall in each of the two periods, and, indeed, during the whole year, shows great annual variation. The winter and spring showers may be very local. There are not only con-

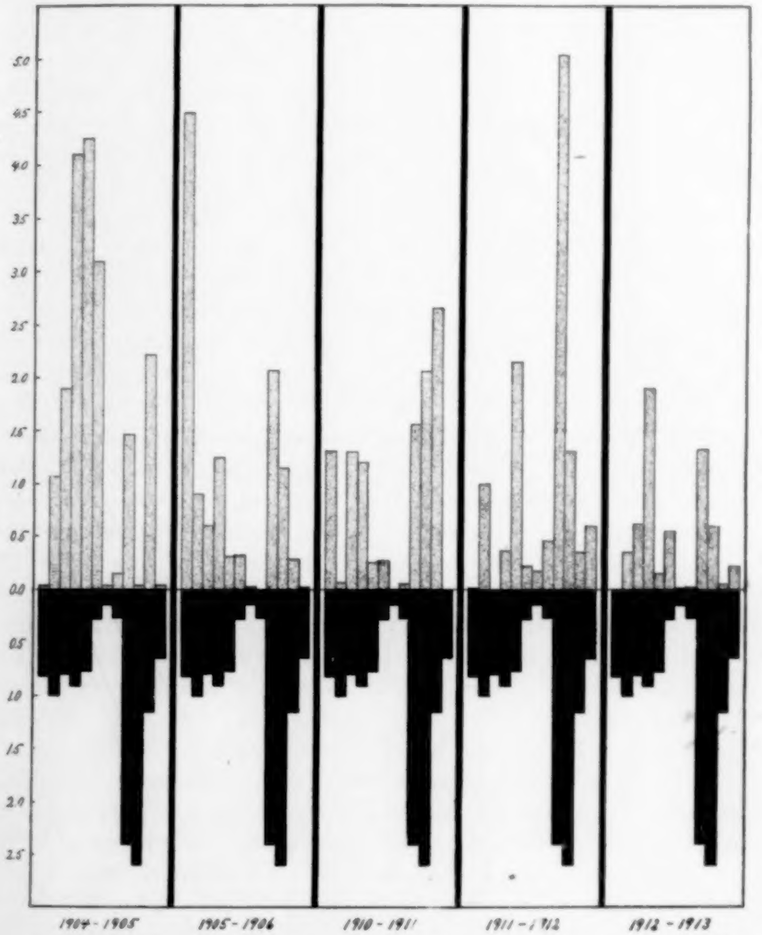

FIG. 1. In this figure are shown the monthly precipitation for five individual periods each of a biological year, beginning with November and ending with October. The rains falling in November and subsequent winter months are chiefly of significance in the development of the winter or spring annuals and in replenishing the reserve of the cacti. The rains falling in October may complete the development of the plants of the second, midsummer, period of growth.

Note that there is not only a division into two distinct rainy seasons which recur annually, but that there is great variation in the amount and time of rainfall from year to year.

The dark area is the average for fifteen years as given by MacDougal. It is repeated under each year to show the extent of variation from the average.

spicuous differences from year to year, but in the same year tracts, only a few hours' ride apart, vary greatly in the state of development of their vegetation.

The soil moisture of a region so variable in rainfall and so diverse in surface topography and in depth and texture (and consequently in water-absorbing power and retaining capacity) as the environs of Tucson, presents a problem of great complexity, even if one considers it from the physical side alone, and not in its more complicated relation to the plant organism.

One must remember that the water which is of service to the plant is not the amount recorded by the rain gauge. Only a portion of the water, falling upon a given spot, may become soil moisture for the plants which grow there. Besides the loss through superficial run off already indicated, there is unquestionably a sub-surface drainage which, when there is sufficient precipitation to bring it about, tends to irrigate some spots at the expense of others. In consequence, there is great variation in soil moisture in habitats otherwise apparently uniform.

By no means all of the water which sinks into the soil can be used. In the development of every plant organism there is a time factor. While physiological processes are carried through with great rapidity in desert plants, there is a minimum beyond which this time element can not be reduced. *Duration* of soil moisture, not merely *absolute amount,* is of great importance.

With regard to the permanence of soil moisture, the various habitats differ widely. Cannon has found that the upper levels of the soil of the bajadas were air dry at the end of three weeks after the rains, while those of Tumamoc Hill and of the Santa Cruz flood plain remained moist for a period exceeding six weeks. On Tumamoc Hill, the superficial soil layer may be so thoroughly baked during the dry fore-summer that the water content falls to about 2 per cent. of its volume; but beneath, the water supply is probably adequate for the growth of the more hardy and deeper-rooted shrubs, throughout the periods when other conditions are favorable. Anomalous as it may seem, the great evaporating power of the air is the cause of the retention of the considerable quantities of moisture in the lower layers of the soil—at a depth available to many perennials and in amounts sufficient for life and even growth during dry seasons. From the surface layers, evaporation is so rapid after a rain that a dry mulch is formed, preventing more or less effectively the loss of water from beneath.

Temperature shows not merely a fluctuation of over 100 degrees Fahrenheit during the year, *all falling above zero,* but great diurnal variation as well. In the growing and even flowering season of the winter annuals, the days are warm—or hot, in the terminology of the more temperate regions,—while the nights have freezing temperature.

A skim of ice may form over one's aluminum drinking cup at breakfast before he breaks camp to collect the earliest flowering winter annuals.

Topographic irregularities greatly complicate temperature relationships. Southern species may have their northernmost limits of distribution on the southwestern slopes of the rocky hills. Here the temperature is far higher than over the crests where cold winds sweep against their northern slopes. It is in such localities that the splendid organ cactus, or pitahaya, flourishes, apparently beyond its reproductive limits, in the Cababi hills.

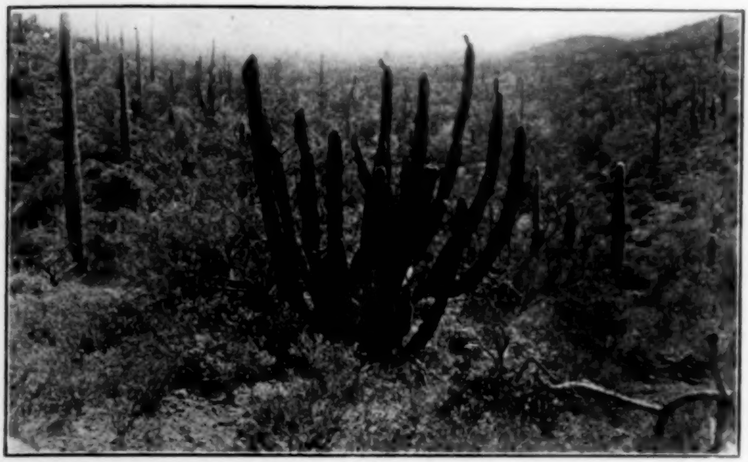

FIG. 2. Northeasternmost limit of the Organ Cactus, or Pitahaya, in a protected valley of the Cababi Hills about seventy-five miles southwest of Tucson, opening towards the Mexican desert. Here it is growing among the columnar giant cacti and a thick stand of half shrubs which are characteristic of the rocky slopes.

It is in these deserts that the temperature environments, which one might predict, from commonly accepted rules, are apt to be modified by the phenomenon which MacDougal has designated as Cold Air Drainage. During the night the air from higher levels, becoming cooled, flows down the rocky slopes through the canyons, where it may form true aereal rivers, and into the valleys where it lowers the night temperatures of the plant organisms.

The naturalist, trained in a region where there is not a great diurnal heating of the earth's surface and a rapid nocturnal radiation of heat from a rocky dry soil, relatively unprotected by vegetation, is apt to think of this factor as one that might be demonstrated to exist only by long series of exact instrumental observations. On the contrary, the phenomenon is readily appreciable. A beautiful demonstration is to be seen from Tumamoc Hill. In the early morning, the broad valley of the Santa Cruz seems filled with fog. This is really the mesquite smoke of Tucson carried down by the cold air drainage from the higher-

lying plains towards the Gila Valley to the northwest. Above the village, the smoke curls high and irregular; below, it is drawn into the cold air current and borne down the valley in a stream whose upper limits seem marked off along the bajadas of the Santa Catalinas with almost the linearity of the draftsman's T-square.

Shreve has shown that the temperatures in the valley may, in consequence of this factor, be many degrees below those of the hill.

When the temperature becomes sufficiently high—although absolutely it is very low—for the germination of the winter annuals the soil is apt to contain a moderate amount of moisture, at a little distance below the surface, but remains always at a relatively low temperature. Thus, although the soil surface and the sub-aereal parts of the plant (the stems and leaves) may be exposed to rather intense heat during the day, the more deeply penetrating roots are subjected continuously to the retarding influence of low temperature, while the shoots must carry on their physiological activities under the influence of alternating high and low temperatures.

The summer annuals, on the other hand, germinate after the rains have not only soaked but cooled the superficial layers of a substratum which has been both dried and heated to a great depth by the intense insolation of the fore-summer. Thus, their roots develop under conditions of favorable temperature at least, and generally of both temperature and moisture. The summer rains cool the air and change the atmosphere conditions from those of intense heat and enormous evaporating power to those of high relative humidity. Thus there is a brief period of optimum conditions for the luxuriant growth of plants with extensive leaf development. Relative humidity may range from 10 per cent. to saturation. In its relation to the evaporating power of the air and consequently to transpiration, variation in relative humidity is a factor of fundamental biological significance.

Such, briefly, are the salient physical features of the region. It is evident that the plants which inhabit it must derive their water from rainfall, not only meager in quantity, but irregular in local and temporal distribution, and which fails, to a great and highly variable extent, to penetrate into the substratum. This moisture they must draw from a soil irregular in depth and texture and in water-holding capacity and sometimes highly impregnated by mineral salts. Saturation of the soil for brief periods is followed by a condition of complete dryness in most localities. In others, deep-rooted species may obtain water throughout the year. All their physiological processes must be carried out under widely ranging temperatures. Their aereal shoots are exposed to intense insolation in an atmosphere which is generally dry, and often moving at a considerable velocity. Brief periods of high relative humidity may alternate with those of excessive evaporating power of the air.

Thus in every factor there is conspicuous environmental heterogeneity or variability. What are the consequences for living organisms?

First of all, the distribution of the rainfall in two seasons separated by a period of intense heat and dryness, in a region affording sufficient temperature for growth throughout the greater part of the year, results in two distinct vegetative seasons. The first is the period of winter and spring annuals, shrubby or frutescent perennials. The second is that of summer annuals and frutescent and arborescent perennials.

The annuals developing in the winter and spring months and those appearing after the torrential rains during the heat of July and August are not only subjected to widely different conditions of growth, but are specifically distinct and physiologically dissimilar. The life cycle of these winter annuals may be short or long, depending upon the distribution of temperature. They may germinate and begin growth with November rains and mark time in development throughout the colder winter months, and complete vegetation and fruition with the precipitation of February and March and the warmth of March and April. On the other hand, germination and initial growth may be delayed by low temperature and inadequate moisture until well into March, when, if water is scarce and temperature high, the whole life cycle of the plant may be of remarkable brevity. Under these circumstances, many of the plants open their flowers and even nearly or quite mature their fruits with the cotyledons still apparently functional.

If the winter rains be supplemented by heavy spring showers, the winter annuals, which would otherwise be dwarfed, except in the most favored spots, may show long-continued growth and attain a large size.

While the winter and summer annuals pass the periods of greatest extremes of temperature and of dryness in the form of resistant seeds, the woody perennials must remain exposed to the most extreme conditions of the year. In their physiological activities, they show the greatest diversity. Some respond to the winter moisture and spring warmth by foliation and fruition. Others lie dormant throughout the first growing season to burst into leaf and flower after the heavy summer rains. Some are physiologically active in one growing season only, others in both. *Fouquieria* loses its tender leaves whenever the soil becomes too dry, and clothes itself with green again, whenever temperature and soil moisture are favorable. *Mortonia* retains its tough leaves for years.

The second consequence of the division of the rainfall into two seasons, instead of one period of precipitation, usually found in desert regions, is a fairly luxuriant growth of tree-like perennials, as well as of small rapidly maturing annuals. Thus, these southwestern deserts have fittingly been called arboreal deserts; the greenest of all deserts.

It is this covering of trees, often mere shrubs, if size be the criterion

FIG. 3. Spreading arborescent cactus, *Opuntia* sp. growing near Hayes's Well, about forty miles southwest of Tucson. Mesquite trees in the background. The grass in the foreground is unusually abundant. Photograph by Dr. MacDougal.

of classification, but trees, properly so called, if age be taken into account, which takes away the monotony of the stones, gravel and adobe, only to replace it for the average traveler by a monotony of cacti, yuccas and agaves, scattered shrubby bushes or small trees—for the smaller plants are seen only at limited seasons of the year and are commonly not visible from the Pullman window.

FIG. 4. Young giant cacti or Sahuaros growing among spinose ligneous plants. Note the more mature giant cacti and mesquite trees in the background and the smaller shrubs and the procumbent platyopuntas in the foreground where the mesa floor is bare of most other vegetation. Photograph by Dr. MacDougal.

But the subjective monotony of the traveler has no objective reality in the paucity of conspicuous forms. Among the cacti, there are the generally procumbent flat-stemmed opuntias, or prickly pears, the shrub or tree-like round-stemmed opuntias, *Cylindropuntias,* or *chollas,* the barrel cacti, or bisnagas and above all the splendid fluted columns of the giant cactus or *sahuaro.* The latter is represented by but a single species, but there are five or six quite distinct and highly interesting round-stemmed cacti that are indifferently called *chollas* and a score of species of prickly pears and other cacti that can not be distinguished from a distance. When leafless, two acacias will not be distinguished by the novice from the mesquite belonging to quite a different genus. Add to these the palo verde, the ocatillo, the yuccas and agaves, *Dasylirion,* the omnipresent creosote bush and several other shrubs, which are less dominant in the facies of the vegetation: a respectable beginning, then, has been made upon a rather thick flora of the region.

In fact, the flora is not at all meager. The paucity of species is only apparent; it arises from the facts that only the more conspicuous ones are seen at all by the average tourist, that things which are quite distinct are liable to be confused, that those which do occur together in the same plant association are not all in a vegetative condition, and hence not easily distinguished by the novice, at the same time.

Standing as it does in a transition zone between the highlands of New Mexico and of northern and eastern Arizona and the great desert that stretches away southwest to the Colorado delta, with the valley of the Santa Cruz connecting it with the Sonoran Highlands on the south, with the diversity in environmental conditions which accompany a range of elevation of several thousands of feet within a radius of but a relatively few miles, it is inevitable that this region would exhibit a marvelous commingling of taxonomically and floristically diverse plant organisms.

The bare statement that the region contains a flora rich in genera and species and of diverse geographic origin or affinity is entirely inadequate as a description of its real biological diversity. The plants which one sees are of the most highly contrasted structural types.

Some few species have roots extending far down to a permanent water supply, in the few places where this is possible, others have a spreading underground system lying immediately beneath the surface. Growing side by side, one may see large bisnagas or magnificent sahuaros, whose stems contain hundreds or thousands of liters of water and hard dry-stemmed shrubs. During the brief moist seasons, plants with leaves as tender as those of our eastern forests hasten through their development in the shade of tiny-leaved trees, many of which, notwithstanding their small size, were old before the Spanish came down through the valley of

the Santa Cruz. Rooted in the same soil, one may find species whose juice shows high and others whose cell sap shows low concentrations.

Thus diversity or differentiation in the living organisms is not structural merely. After a few weeks in the field, the observer will realize, more fully than he has ever before, that the distinctions between species are not solely of the kind that can be drawn or photographed or ascertained by inspection of that sacred and indispensable mummy, the type specimen. The species of plants are not merely externally dissimilar, but inherently very diverse; they are not merely morphologically differentiated but physiologically very distinct; they are to be distinguished not merely by their external form, but by their methods of reaction to the various factors of their environment.

In the greatest variety of ways these morphological and physiological differences are exhibited. Many of these have been briefly indicated in foregoing paragraphs. To enumerate in greater detail, the diverse modifications of the structural elements of which the flowering plant is typically built up or the variety of response to environmental factors would carry us too far into technical descriptions.

It is this great complexity of environment and this diversity of organisms which render the southwestern desert one of the most fascinating and profitable of all regions to the biologist, whether by specialization taxonomist, morphologist, physiologist or evolutionist.

THE INFLUENCE OF GREECE ON SCIENCE AND MEDICINE

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IT may be said without inaccuracy that in ancient Greece we find either the beginnings or the indications of every phase of intellectual activity characteristic of our present civilization, not excepting either the study of science or the practise of medicine. Were one of the Greeks of the age of Archimedes to appear to-day in the midst of our university activities, he would be surprised not at our study of philosophy or logic, or ethics, or mathematics, or languages, but at the state of those applied sciences which deal quantitatively with the various forms of natural energy. That we can measure the force of gravitation, or the rate of transference of heat or the quantity of heat transferred, that we employ the expansive force of steam, or the differences of electrical potential in order to make things move—these would indeed amaze him. Aristotle, for instance, would be dumfounded to be told that an egg could be hatched by the artificial heat of an incubator, for he taught that there was a very great difference between heat of physical and of animal origin; in fact, that they were absolutely distinct in their essence.

That one might contemplate natural happenings and distinguish their essence from their accidents, the Greek mind could comprehend; but what is so entirely modern is the way in which we have liberated and utilized the natural forces and incarnated energy, harnessed force to matter, and made energy manifest by transmuting one form of it into some other.

Man's muscles are of so much less account to-day than any ancient Greek would have dreamed it possible.

The Greek contributions to the science of mathematics are matters of common knowledge: almost every one knows that Euclid is the name of a mathematician and not of a subject; although we have heard of a schoolboy who, on being shown a bust of Euclid, asked, "Why didn't they have one of good old Algebra too?" The Greek did what he could—and it must be confessed very successfully—to study the properties of space, since it was denied him to investigate the forces operating in that space. He developed the science of pure spatial relationships; and although the name of Euclid is the best known of the geometers, it is far from being the only one. The Pythagoreans had investigated dimensions and quantities; Apollonius of Perga, conic sections, Archimedes mechanics, Heron hydrostatics, Diophantus arithmetic and al-

gebra; Eudoxus and Hipparchus, astronomy. Grecian architecture was the outcome of scientific principles just as much as of the perception of the beautiful. The columns of the temples were so constructed as to appear from the ground correct in outline and perspective, although in many cases they were neither vertical nor were their sides parallel. Euclid gives a full treatment of the mathematical principles of stereoscopic vision, as also does Galen.

If science is knowledge based on or flowing from exact thinking, the Greeks possessed such science, and laid down for all succeeding generations the philosophical basis for the superstructure.

There were natural philosophers as distinguished from metaphysicians from the earliest times. Aristotle and his pupils subsidized by Alexander the Great made vast collections of facts as truly empirical as those of any laborious collector or systematist of the present day. This spade-work in science was certainly less congenial to the Grecian mind than speculation; but some one had to do the spade-work and even that was not shirked. To the Greek mind the mere specialist or technician would have been deemed a monstrosity or a barbarian. To a person to-day who had acquired the facts of chemistry, let us say, without a knowledge of logic, mathematics, metaphysics, music, astronomy and modern languages, the Greeks would never have given the name of "scientist."

The Greeks cultivated the objective sciences with conspicuous success; they gathered facts in astronomy, optics, geography, zoology, embryology, botany and medicine, in very much the same general way that we do now. Without instruments of precision, they observed so precisely as to predict eclipses successfully. The universe, the environment, was to the Greeks a constant source of interest and of material for analysis; and this study of nature did not in the least impair their contemplation of the beautiful, the powerful, the graceful or the symmetrical.

But when we say "the Greeks," we do not confine our attention to thinkers within the geographical confines of Greece itself, we must include such seats of intellectual activity as her colonies at Pergamos and at Alexandria. Euclid, who left a certain portion of mathematics so complete that nothing was added to it until the seventeenth century A.D., was a resident in Alexandria and he flourished in the reign of Ptolemy I., King of Egypt (Ptolemy Soter who reigned from 323 to 285 B.C.). Euclid, who may have been born about 300 B.C., was one of the chief ornaments of that learned society at Alexandria which one, nowadays, would call a university, for it included philosophers, astronomers, mathematicians, physicians and anatomists. Not, of course, that Euclid really was the author of all the books extant and lost which have been attributed to him; for Proposition 47 of the First Book (In every

right-angled triangle, the square on the hypotenuse is equal to the sum of the squares on the other sides) was the discovery of Pythagoras; while Theon of Alexandria is known to have added certain definitions on his own account.

But even when we deduct all those portions of Grecian geometry declared by scholars to be earlier or later than Euclid, we are left paralyzed in admiration of the mind of the one man who was author of what is left.

We have no details of the life of Euclid; only one of his sayings has come down to us. When Ptolemy asked him if a person could not understand geometry without reading all his books—an enquiry with which many school boys in all ages have been in the deepest sympathy—Euclid replied: "There are no royal roads to geometry," alluding to those straight roads in Persia which were reserved for the king alone to travel over.

After Euclid, probably the next best known Greek mathematician is Archimedes, who in his youth studied at the Alexandrian School. Unquestionably the most original of the Greeks, Archimedes invented appliances and enunciated principles which remain of the utmost utility at the present day. The endless or Archimedean screw, although not now used for the purpose for which it was originally devised (raising water from the hold of a ship), is the parent of such diverse mechanisms as screw-nails and the steam-turbine. Archimedes made the first planetarium. His "Eureka" on discovering a method to detect alloy in the gold crown of Hiero of Syracuse, has become a hackneyed phrase. While we need not believe all that was told of him, of his engines for prolonging the siege of Syracuse, of the mirrors with which he set fire to the ships of the Roman fleet, etc., yet we may freely admit Archimedes to have been a mathematician and engineer of the first rank. The Archimedean principle of flotation underlies the possibility of things heavier than water floating in water. One of the sayings of Archimedes is in praise of the lever, a mode of the application of force which we have good reason to believe was known to the Egyptians long before Greece was civilized. Archimedes wrote, or to his inspiration are attributed, quite a number of books on pure mathematics, both of surfaces and solids, one of them, a treatise on the center of inertia, being of practical value at the present day. This book is regarded as the foundation of the theory of mechanics and it is a great advance on what Aristotle wrote on the same subject. By his own desire, the figure of a sphere within a cylinder was engraved on his tomb, for it was the relationship of these which Archimedes considered his greatest discovery. Archimedes was killed by a Roman soldier on the fall of Syracuse in 212 B.C. Cicero in 75 B.C. found the tomb overgrown with vegetation. Hero of Alexandria in his "Pneumatica" describes at least two devices

where either hot air or steam was made to do mechanical work. The one is a primitive type of steam-turbine, the other is the prototype of a class of engine which only after many centuries became practically useful.

Probably astronomy of all the objective sciences was that which the Greeks cultivated most successfully. This is not the occasion on which to relate even in epitomized form the evolution of astronomical knowledge among the ancients. From Thales of Miletus, who lived about 600 years B.C., to Ptolemy who flourished at Alexandria, about the 130th year of our own era, the knowledge of the behavior of the heavenly bodies had become increasingly more exact. Thales predicted an eclipse which "came off," if we may apply so irreverent a phrase to such event, on May 25, 585 B.C. Not that Ptolemy was the greatest, because one of the latest, of the Grecian astronomers. The discoveries of Hipparchus of Rhodes, in the opinion of modern astronomers are much more important. Not only was the observation of the eccentricity of the lunar orbit made by Hipparchus, but his observations on the motions of the moon became the data which enabled Dr. Halley in the eighteenth century to apply a most delicate test—the acceleration of the mean lunar motion—to Newton's great law of universal gravitation.

But the astronomical system of Pythagoras was actually nearer to the truth than was the Ptolemaic, for, for one thing, it made day and night depend upon the earth's rotation. He postulated a proper motion for the earth, and was thus more correct than Ptolemy. The system of Copernicus was more similar to the earlier than to the later Greek view; and, indeed, it was one of the charges brought by the church against Copernicus that his system was heathen and "Pythagorean." Anaximander made the first map of the heavens.

While we cannot speak of the science of chemistry as having existed in classical ages, since by "chemistry" we mean nothing earlier than the time of Van Helmont, yet every one knows that the Greeks speculated on the ultimate constitution of matter and on the substance of the universe with as much zest as they did on the constitution and nature of mind. The concept of the atom is purely Greek. Doubtless Dalton meant by "atom" something much more definite than did Leucippus or Democritus; but we cannot admit that Dalton's conception of the ultimate structure of matter was, as an intellectual analysis, any more subtle than that other which was the earlier by two thousand years.

Both Thales and Anaximander spoke of a universally distributed, primitive world-stuff, whether moisture, caloric, ether, was not determined, some one thing eternally abiding although its forms were many and evanescent. This does not differ essentially from the modern conception of the all-pervading ether whose properties underlie the forms of grosser matter.

The notion that matter could be, at least in thought, analyzed down to ultimate atoms, that is, bodies incapable of being further divided, was in no wise due to Dalton, but was adopted by him as the only reasonable hypothesis of the ultimate constitution of matter. Democritus further assumed that the atoms, rotating as they were imagined to do, must collide with one another, as a result of which certain properties of matter were established. This is virtually none other than the modern "kinetic theory of gases."

To Aristotle the inherent motion of the atoms was a difficulty; but this is a difficulty only to one who assumes that rest is more primitive, more of the original state, than motion. Our latest view is the early Grecian—that everything is in motion, and nothing is at rest, that rest is a relationship, the illusory result of movements in opposite directions.

That substance is infinitely extended and is primally one, that it is possessed of inherent motion, are Greek conceptions which though modified by centuries of subsequent thinking, are still of the warp and woof of modern physico-chemical working ideas.

Parmenides wrote on the oneness of substance, and was thence led in the sphere of religion to Pantheism.

It is admitted that Pythagoras and his school founded the science of mathematics and indeed gave the very *name* to the study. The Pythagoreans raised geometry to a pure science, severing it from its earlier association with the means of measuring actual distances on the earth's surface (mensuration). The Pythagoreans instituted the quadrivium or fourfold way to knowledge—the study of logic, rhetoric, geometry and astronomy—which lasted until the close of the middle ages and was always contrasted with the trivium or junior course of grammar, arithmetic and music. It is really to Pythagoras that the retaining of geometry and mathematics as a compulsory subject in all higher education is due; and we are sure that he has been thoroughly cursed by many generations of classically-minded but mathematically-incompetent aspirants after the degree of Artium Magister.

Pythagoras is also responsible for all the curious fancies about numbers such as, the odd and even, lucky or unlucky, right and left, dark and light, the good and evil numbers. He even attributed sex to numbers; three was male and two female, therefore five symbolized marriage.

These ideas linger on to this day: I have heard people tell me that if there were 7 of a thing, all must be well, since 7 is a "perfect number"; and I am repeatedly informed that some number or other is unlucky. The theory of numbers was of course illustrated in the 7 planets—the heavenly heptachord, which, being perfect, could not do otherwise than make "the music of the spheres." Pythagoras, however, did discover the objective vibrational relationships between the various tones in an octave.

Possibly Pythagoras is best known to people generally as the originator of the doctrine of metempsychosis, the transmigration of souls. To do penance for sins, the soul of a man might have to inhabit the body of a lower animal, *i.e.*, undergo a lower reincarnation. You remember when Malvolio is in prison[1] the clown, disguised as a priest, asks him:

C. What is the opinion of Pythagoras concerning wild-fowl?
M. That the soul of our grandam might haply inhabit a bird.
C. What thinkest thou of his opinion?
M. I think nobly of the soul, and in no way approve his opinion.
C. Fare thee well, remain thou still in darkness; thou shalt hold the opinion of Pythagoras ere I will allow of thy wits and fear to kill a woodcock lest thou dispossess the soul of thy grandam.

So that the origin of this joking was, by Shakespeare's day, already 2,000 years old.

The writings of Aristotle which deal with zoology and embryology are so well known that they need only be mentioned at this time. Of course it would be easy to show in how many things he was mistaken in regard to animal structure and function, nevertheless he was the first systematic student of zoology.

Long before Aristotle's time, however, Thales (639–544 B.C.) had speculated that all kinds of life, animal and vegetable, were derived from some one, common, living substance, thus anticipating our conception of protoplasm by about twenty-three centuries.

Empedocles of Agrigentum (504–443) wrote on the development of the fetus, and gave us the terms amnion and chorion which are in use at the present day. Anaxagoras had pondered on the power which the various organs of the body have of absorbing different forms of nourishment from the common blood. It is an unsolved problem yet.

No doubt there was the practise of the healing art before Hippocrates, just as there were poets before Homer. A learned German has collected all the allusions to physicians or the healing art in Greek poetry before the time of Hippocrates. It appears that such medical knowledge as existed before Homer was all of Egyptian origin. Homer mentions bones, sinews and intestines. He alludes to wounds and to the activities of surgeons with the army in the Troad, but never mentions internal diseases. He speaks of a woman Agamede who knew of all the healing herbs, and of Helen giving Telemachus nepenthe or the drink of oblivion. The onion, honey and wine are mentioned as drugs; and the bath followed by inunction as a therapeutic measure. Homer names two medical men, Machaon and Podalirius, sons of Asclepios, an unrivalled physician. Of the former he said:

A wise physician skilled our wounds to heal
Is more than armies to the public weal.

[1] "Twelfth Night," Act IV., Sc. II.

That Xenophon, for example, recommended black as a restorative in cases of snow-blindness, does not entitle us to suppose that therefore Xenophon had any medical knowledge.

Hippocrates the Great was certainly the first in Greece to commit to writing a body of knowledge dealing with the diagnosis, treatment and prognosis of disease.

It is usual to trace the origin of Greek medicine to the worship of Asclepios (Latiné, Æsculapius) the God of Healing, son of Apollo. The cult of Asclepios was certainly very old and probably modelled on Egyptian lines. Sick people were brought to the temples of Asclepios just as to-day in Roman Catholic countries invalids are brought to shrines, or in all countries to spas or watering-places.

The priests of Asclepios or the Asclepiadae were not physicians so much as men who mingled with their religious activities a considerable amount of common-sense regarding the therapeutic power of mental suggestion. Hippocrates, who was not an Asclepiad but the chief personage at the medical school of the island of Cos, belongs to the age of Pericles. It is proper that in the golden age of Greece's history, the Father of Medicine should have arisen. He is supposed to have been the son of Heraclides, an Asclepiad, and the midwife Phænarete, and to have been born about 460 B.C.

The deservedly great fame of Hippocrates rests on his insistence that disease is a natural phenomenon, not some visitation of supernatural origin. He studies the sick man as a whole, entirely in the modern spirit, recognizing that we must observe closely in order first to learn the facts of the ailment, obtaining the natural history of the disease, and must recognize all the time that nature is in the main striving towards the recovery of the health. Of course some previous theoretical guidance was assumed necessary, but Hippocrates came each day to a case like an unbiased natural philosopher approaching some problem new to him.

In its Latin dress of vix medicatrix Naturæ, the healing tendency of living matter is familiar to most of us. A great deal of the so-called Hippocratic writings are not from the hand of Hippocrates, many being later than his time; but enough that are genuine remain to convince us how high were the ideals of Hippocrates in the sphere of morals, no less than in that of medicine. The oath of Hippocrates is a noble document. Whether it was composed by Hippocrates himself may be doubted, but it accurately represents the high aims that Hippocrates had before him in his practise. Composed as it was in times long pre-Christian, it is to-day as worthy a guide for the conduct of the physician as can be found in any literature; and its obligation to keep professional secrets may well be pondered over by those members of our profession, who, in neglecting this part of the oath, are guilty of a grave offence against

the ethics of their calling. I need hardly say that the "Aphorisms of Hippocrates" have long ago taken their place immovably amongst the world's classics.

Many more doctrines in medicine are due to Hippocrates than most people, even most physicians, believe. The doctrine of humors, of the healing power of nature, of critical days (this latter the result of Pythagorean influence), are all Hippocratic; while "Hippocratic succession" and the "facies Hippocratica" have been an integral part of medical terminology for 2,300 years. Hippocrates recognized four humors, blood, phlegm, yellow bile and black bile, a proper or due mixing of which constituted good health, an undue predominance of any one, disease, notions which gave rise to the "humoral pathology" which dominated medicine for ages, and which in another sense dominates it still. Hippocrates, as one might suppose, had a much better knowledge of the bodily organs than of their functions. He certainly confused nerves, tendons and ligaments, a mistake quite excusable, seeing that they are all very similar in the dead body of a lower animal; for there is no evidence that Hippocrates examined the body of any animal during its life. In all probability he did not even dissect the human body. The bare idea of doing so would have been repugnant to the beauty-loving Greek. Some of the Hippocratic physiology is not far from the truth, some of it far indeed. He knew that food was "cooked" in the stomach, that a lesion on one side of the brain produces paralysis on the opposite side of the body, that the heart contains blood, that the liver prepares blood and bile, and that the lens of the eye has to do with vision. He knew that local fatigue could, if sufficiently developed, produce general fatigue. Hippocrates divided diseases into chronic and acute, endemic and epidemic, distinctions we recognize yet.

Again the terms angina, catharsis, catarrh, enema, paracentesis, glaucoma, gangrene, syncope, hemorrhage, "healing by the first intention," are all terms of Hippocratic medicine in use to-day. The Father of Medicine wrote on the principles of surgery, obstetrics, dietetics and treatment. As regards treatment he was thoroughly eclectic, using every means in his power to restore the sick man to health. The modern treatment of fevers is essentially Hippocratic; febrile patients were allowed to drink water or barley water; later medicine, arriving at the doctrine that water was injurious to the fevered organism, practised much unconscious cruelty and undoubtedly sacrificed many lives.

Hippocrates is the all-round physician; he knows all that has gone before in his science. "The physician," he says, "must know what his predecessors have known if he does not wish to deceive both himself and others." He studies everything concerning his patient, his heredity, the objective signs, and the subjective when he can elicit them. His profession is to him as art to the artist: "Where is love for art, there

is also love for man." Hippocrates is the good physician, at the very ethical antipodes from the quack or mere drug-prescriber. His is the large, sympathetic, wise, tactful, kindly outlook not so much towards disease as the diseased man; he is the exponent of the highest Greek culture in the realm of applied medicine. Although the schools of Cos and of Cnidos continued for a long time to exert their influence, with Hippocrates and Pericles passed away the brightest hour of Greece's glory at least in matters medical. The succeeding century was comparatively sterile as regards contributions to practical medicine.

For although Plato wrote on certain matters belonging, as we should now think, to medical science, his influence built up the school of the Dogmatists whose chief tenet was that reflection should come before experience. In fact, philosophizing about disease rather than the observing of patients became the vogue in some quarters, so that much post-Hippocratic medicine is clinically barren. It may be doubted whether Plato understood more perfectly than Hippocrates any bodily function, save perhaps the respiration. Plato's doctrine of the soul as a separate existence, residing in the "marrow" (presumably the central nervous system, not the bone-marrow), concerns us here only in so far as we see specified one of the earliest seats of the soul and that a neural one. Chrysippus of Cnidos (born B.C. 340) regarded the soul as being in the blood, on which account he would not employ venesection, but did use tourniquets on bleeding limbs. Both Pythagoras and the Egyptians had taught that the soul was in the blood, a view consonant with that in the Old Testament, "for the blood is the life." According to Professor Ostwald, Plato is responsible for all the difficulty in connection with the problem of the relationship of mind to matter. His words are:

> Through the age-long effect of the blunder committed by Plato in making a fundamental distinction between mental life and physical life, we experience the utmost difficulty in habituating ourselves to the thought of the regular connection between the simplest physiological and the highest intellectual acts.

Praxagoras of Cos was the teacher of Herophilus, himself one of the best known teachers of that important school of medicine or university at Alexandria which was founded by Ptolemy Soter and continued to be a source of Hellenic illumination as late as the second century of our own era.

Praxagoras it was who, first distinguishing arteries from veins, taught that in health the arteries did not contain blood, but that, as blood always flowed from them in wounds, they must have taken it up from the flesh round about.

The other famous name of the Alexandrian Museum was Erasistratus, whose teacher had been Metrodorus, the son-in-law of Aristotle. By the mention of that great name, probably the greatest of antiquity, we are introduced not only to the encyclopedist of Hellenic science, but to

an influence which exerted itself in ever increasing force almost to within our own day. For, as Professor Mahaffy says, the man whose writings dominated European thought in logic and in the mental and physical sciences for more than a millennium, and who came within a very little of being canonized by the church of Rome, was probably the greatest of the ancients. Aristotle was as much the creator of the science of logic as he was of the sciences of zoology, embryology and comparative anatomy. He discovered the heart of the unhatched chick (punctum saliens) and saw it pulsating. He named the great artery that proceeds from the heart, aorta, by which term it has ever since been known. He adopted the Hippocratic classification of the humors, but did not rectify the confusing of nerves with tendons. He distinguished arteries from veins; but he described a vein from the liver to the right arm, and another from the spleen to the left arm, hence blood letting on the same side as the organ affected was especially valuable. This error gave rise to a long controversy during the Middle Ages as to where to open a vein; entire medical schools, even whole universities, being ranged on one side and on the other.

To Aristotle the heart is the acropolis of the body, and he makes the neura or tendons arise from the heart. The nerves, as canals leading from the brain, he understands, but, believing the brain to be bloodless, he attributes no functions of any great importance to it. The object of respiration he imagined to be the drawing in of cold air to cool "the innate heat of the heart," a view which was held until the time of Harvey. As Professor Driesch says:

> What inspires us with the highest admiration of the great Greek thinker is the way in which he perpetually and manifestly struggles for clearness in this hardest of all Nature's problems (life).

Aristotle frequently writes with his eye on the medical profession. He says:

> It is the business of the naturalist to know also the causes of health and disease, hence most naturalists see in medicine the conclusion of their studies; and of physicians, those at least who display some scientific knowledge in the practise of their art, begin the study of medicine with the natural sciences,

so that custom at least is as old as the time of Aristotle.

But this is, indeed, a late date to be telling people what Aristotle did for every department of knowledge to which he had access. His writings were the academic text-books of the Middle Ages; and the study of them is by no means dispensed with at our seats of learning to-day.

From about 300 B.C. onwards for several hundreds of years, medicine flourished in particular in two Greek colonies, Alexandria in Egypt and Pergamos in Mysia. Both were populous and rich cities, centers of all manner of intellectual and artistic activities.

Alexandria beecame the seat of the most important university of antiquity: all the branches of study were represented there, and anatomy and medicine were taught with a thoroughness nowhere else attained except at Pergamos. To have studied at Alexandria was, as late as the end of the fourth century A.D., the highest recommendation a physician could give.

Herophilus of Chalcedon (335–280), who was physician to Ptolemy I. (323–284), and Erasistratus of Iulis, in later life physician to Ptolemy Philadelphus (284–246), may be regarded as the founders of the Alexandrian school of medicine. The views of these two leaders were not identical, so that in course of time two distinct lines of medical dogma became established, those of the Herophilists and of the Erasistratans, respectively.

The advances in medical knowledge made at Alexandria were due to the untrammelled study of practical human anatomy. Herophilus, it is said, went so far as to dissect living persons, criminals assigned to him by the authorities.

Herophilus left his impress on anatomy for all time: he discovered the meeting-place of the cerebral sinuses in the occipital region, naming it the torcular; he gave its name to the duodenum, he called the pulmonary artery the vena arteriosa, and the pulmonary vein, the arteria venosa. He correctly taught that the pulse is due to the heart's systole, and he knew that arteries contain blood. He described the liver, the oviducts, the hyoid bone and many details in the anatomy of the eye. Herophilus traced nerves to and from the central nervous system, and, describing the brain, gave to an appearance in the Fourth Ventricle the name of Calamus Scriptorius which it has ever since retained. Herophilus believed the soul resided in the Fourth Ventricle. Herophilus discovered the receptaculum chyli and certain large lymphatics which were rediscovered only in the seventeenth century. Erasistratus made even a more thorough study of the brain than did Herophilus, and attributed mental diseases to lesions of that organ or of the cerebellum. Though he denied that the arteries contain blood, Erasistratus wrote with insight on paralysis, dropsies, liver disease, digestion, absorption and treatment both by drugs and by surgery. Erasistratus is remembered for having diagnosed the cause of the illness of Antiochus, son of Seleucus Nicator, whose physician he was. Erasistratus discovered that the prince was in love with his stepmother, Stratonice, because of his blushing and palpitation whenever that lady entered the room. Erasistratus was evidently a physiologist. Whether or not it was with a view of curing Antiochus, I cannot say, but Erasistratus prescribed marriage with Stratonice, for which advice he received a fee of $100,000.

The following belonged to the school of Herophilus; Demetrius of Apamea (276 B.C.), Collimachus (246 B.C.), Zeuxis of Laodacea, Dio-

scorides (40 B.C.) the physician of Cleopatra, and Aristoxenes (A.D. 79). Demetrius of Bithynia and Heron of Alexandria are well known names in Alexandrine medicine. Heron, a mathematician and physicist as well as physician, was a contemporary of Archimedes; he described a water-organ, the invention of his teacher Ctesibius.

The other great school of medicine in a Grecian colony which alone rivalled Alexandria in learning and culture was Pergamos, that same Pergamos where "Satan's seat is," as it is expressed in the address to the Angel of the church at Pergamos. The library at Pergamos was almost as famous as that at Alexandria: when Ptolemy Soter would not allow the exportation of papyrus from Egypt, the Pergamites used animal skins for their books, hence "parchment."

The age-renowned Galen was a graduate of the school at Pergamos, and the names of his teachers in anatomy and pathology survive to this day. He studied anatomy also at Smyrna under one Pelops, and for some time at Alexandria under Heraclianus. It was here, he says, he had the good fortune to see a human skeleton.

Claudius Galenus (to give him his Latinized name) was a Greek, he wrote in Greek, and his works were not translated into Latin until the fifteenth century. Galen, the son of an architect Nicon, was born at Pergamos in A.D. 130 and died in Rome, it is believed, about the year 200. Nicon, having had a dream bearing on his son's future, devoted him to a study of philosophy and medicine from as early as his fifteenth year. On returniing from his travels to his native city when he was about 28 years old, Galen was appointed surgeon to the school of Gladiators at Pergamos. Six years later he went to Rome where he lectured on physiology and on medicine, it would appear, on Hippocratic lines. He does not seem to have had very amicable relations with his colleagues, so he left Rome for a time and returned to Pergamos. After about a year's absence, he was recalled by the Emperor Marcus Aurelius to whom he became physician. Declining to accompany his master on his military expedition against the Marcomanni, Galen remained in Rome as physician to the Emperor Commodus. Though Galen cetrainly extended the knowledge of both structure and function beyond Hippocratic limits, he corrected, unfortunately, but few of the worst Hippocratic mistakes. It is doubtful whether he ever dissected the human body, for, as Vesalius pointed out, his anatomical descriptions apply chiefly to the monkey and the pig. Hence he commits the serious anatomical error of placing the human heart in the mid-line instead of to the left of it. In physiology he went far beyond Hippocrates, probably because he dissected so many animal types, and certainly because he examined some of them while still alive. Galen was known in Rome as the "wonder worker," on account of his having cured Commodus of a very severe illness.

If Hippocrates is the Father of Medicine, and Aristotle the Father

of Embryology, then Galen is the Father of Experimental Physiology. For he discovered that certain nerves were motor to certain muscles of the back, that the inferior laryngeal nerve was the nerve of voice, that the spinal cord was the conductor of impulses necessary for sensation, and that those crossed from one side to the other in it. Galen recognized thirty pairs of spinal nerves and seven pairs of cranial; he knew of sensory fibers in the abdominal sympathetic, and of the vital importance of the medulla oblongata.

The Galenical doctrine of spirits—natural, animal, vital—dominated physiology for fourteen centuries. Galen corrects Aristotle in making the nerves proceed from the heart, but at the same time he denies that the heart has any nerves of its own. He still thinks that in breathing, air is drawn into the chest to cool the heat of the heart, but he recognizes that "sooty" matter escapes from the lungs; he believes that the liver forms blood from digested food.

Galen knew tears to be the secretion of a gland and not an escape of aqueous humor: he discovered the six pairs of muscles of the eyes, and the muscles of the larynx. It was he who first described the Tendo Achillis, which quite explains why it has a Greek name. Galen's view of structure was always physiological, hence the titles of his works—"De usu partium corporis humani," "De motu musculorum," "De morborum causis." It was on the vascular system that Galen had least light. No notion of a circulation occurred to him. He thought that blood conveyed by the veins to the tissues was there used up in nourishing them. Crude blood with animal spirits from the liver, he thought, passed to the heart where the vital spirits were originated; animal spirits being produced as a further result of a refining process when the arterial blood had reached the brain. "Spirits" are too firmly embedded in our language for us ever to get rid of them. Galen imagined that the blood of the great pulmonary artery went to nourish the substance of the lungs, a notion of which Harvey pointed out the inherent improbability. Galen did, however, discover that an artery has three coats. He insisted that blood passed from the right to the left side of the heart through pores in the septum: Vesalius ridiculed this assertion, Harvey disproved it.

Galen regarded the heart as the seat of courage and the liver of love, a doctrine of local situations for mental attributes which has hardly died out up to the present time. The conceptions of the phrenologists are merely a development of this sort of thing, very different, however, from what is known as the localization of cerebral function. The liver and love were associated as late as Shakespear's time, when Pistol avers that Falstaff loves "with liver burning hot."[2]

Galen is responsible for the well-known doctrine of the four temper-

[2] "Merry Wives," Act II., Sc. I.

aments, the choleric, melancholic, sanguine and lymphatic. He also first gave the so-called four cardinal signs of inflammation: heat, swelling, redness and pain (calor, tumor, rubor and dolor). It is interesting to know that inflammation is possible without any of these four being present. Galen is less of the clinician and more of the systematist than Hippocrates; he is more of the anatomist and physiologist and less of the physician. His writings are very voluminous, for, besides on medical subjects he wrote on philosophical, grammatical, mathematical and legal topics. Forty-eight medical works alone are lost.

There is in Dalhousie University a Latin translation of the works of Galen by a Spaniard, Andreas Lacuna or Laguna, published at Strassburg in 1604, which edition is not in the British Museum.

In a sense it is a fact, then, that all the conceptions which were the intellectual working ideas of the Middle Ages were given to us by the Greeks. The Romans contributed practically nothing to the body of knowledge called science or to that called medicine: Pliny tells us it was beneath the dignity of a Roman to be a physician. Action, not contemplation, was characteristic of the Roman temper.

The fundamental concepts in astronomy, geometry and arithmetic, the entire sciences of logic and ethics; the speculations that were metaphysical, the notion of species, of evolution and yet of the oneness of living matter, the doctrines of the indestructibility of matter, of energy as inherent in matter, of the ultimate atomic constitution of matter were all products of Greek thinking.

The mind of Hellas supplied the materials of thought for subsequent speculation; and in very truth it touched nothing which it did not adorn. From the Greeks we inherit mental subtlety and the analytical aspect of the intellect. The Middle Ages added surprisingly little to this mass of mental currency, though some of the Hellenic coins were sadly defaced by excessive handling. Christianity did indeed introduce certain conceptions far enough removed from anything that the classical ages had attained to, but these were chiefly in the sphere of morals; they were not in objective science. The thinkers of the Ages of Faith made it their concern to mix the philosophy of Plato and the metaphysics of Aristotle with as much of the teaching of the Nazarene as they felt inclined. But with this aspect of things we have no concern to-day, for in "science" I do not for our present purpose include theology. The Middle Ages added no conceptions in regard to the universe or to life as fundamental or as comprehensive as those they inherited from prechristian times. There were, of course, workers like Albertus Magnus and Roger Bacon; but how little encouragement or approval the latter, at any rate, received from his ecclesiastical contemporaries is very well known. Until that awakening of the mind of man known as the Renaissance, not only had thinkers not added anything essential to the body of natural knowledge handed down from antiquity, but a very great deal that the ancients had taught was either distorted or totally forgot-

ten. I will, however, go much farther than that and say that in treatment, our profession up to as late as 100 years ago had forgotten a very deal of the practical therapeutic sanity of the Greeks, and had replaced it by a fantastic and revolting empiricism. The accounts of the doings of medical men at the death-beds of, *e.g.*, Charles the II. or Lord Byron are painful and humiliating, deserving of all the satire which a Molière could invent.

Vulgar representation and monkish credulity were soon mixed up with the few facts of medical learning which had survived the Fall of the Roman Empire. Astrological and alchemical verbiage obscured truths well known 300 years before Christ.

Hippocrates, Aristotle and Galen were not studied in the original, for the language of Greece was both dead and buried, but through Latin translations of Arabic translations. Not only did men not go back to Nature, they did not even go back to the authorities in their original tongues. Trifles of no medical or physiological importance were made the subjects of bitter debates that lasted through many generations.

It was the Arabian physicians who, through their translations of the Greek medical classics, preserved chiefly in Spain the learning of antiquity from suffering extinction during the earlier Middle Ages.

The grand objective simplicity of Hippocrates had given place to pseudo-philosophical and quasi-learned disquisitions about the principles of treatment. Certainly it is true that in every school of medicine the writings of Hippocrates and Galen were the text-books (as when in "The Merry Wives" Evans says, "He has no more knowledge in Hibbocrates and Galen," etc., and again "What says my Æsculapius? My Galen?") The lectures, in fact, consisted in readings from their works and discourses upon what was said therein. In course of time it became a heresy to discover an error in Galencial anatomy, a grave offence to propound a view of functional activity contrary to or beyond that indicated by the Pergamite. This intellectual bondage lasted until the middle of the sixteenth century, when by the boldness and industry of the Belgian Vesalius, and by the originality and candor of the English Harvey, the reformation of anatomy and physiology was accomplished. Vesalius' text-book and Harvey's discovery swept away forever the mental miasms of the Dark Ages. The error of the men of the Middle Ages was not that they revered too much the writings of the great ancients, but in holding that these were beyond criticism and contained the last words in matters medical. The writings of Galen they had allowed to become not merely a great text-book but a work of super-human authority. This was perhaps the greatest honor that the mediocre could pay to the master mind, and that mind the Hellenic. The golden gleam of the glory that was Greece failed not to light as with the kindly glow of a summer evening's sun the thousand years of those ages which, otherwise, would have been dark indeed.

IS A BALANCE OF TRADE IN FAVOR OF EXPORTS FAVORABLE?

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IMAGINE a country or any geographical area, the inhabitants of which trade freely with the rest of the world, but who in all other respects are sufficient unto themselves. That is to say, we suppose the inhabitants not to travel abroad and outsiders not to travel within, and that none of the resources of the country are owned without and that no outside resources are owned within. It is then evident that the imports of the country must be equal to the exports in point of value, that is, the imports are paid for with the exports. And of the actual international trade of the day we may say: "Other things being equal, any change in imports begets an equal change in exports."

Our inquiry divides itself conveniently into three parts. First we will examine this statement as it stands and see how the mechanism of modern trade tends to maintain a balance between imports and exports. We will then examine the gold question. Is it favorable that a country's imports should contain more gold than her exports? The third part of the discussion will consider those less visible factors in international trade which prevent the equality of imports and exports.

The truth of the statement we are first to examine is apparent on *a priori* grounds—value will be given only for value received. But the intermediate steps in the complicated mechanism of trade that brings it about are not so apparent. How, for example, can a new duty restricting imports into the United States also operate to restrict our exports? Supposing, for simplicity, that we are dealing only with Great Britain. Since we now take less from England, English merchants will have less paper demanding gold on the London exchange. A tendency for gold to flow from England to America is set up by the over-supply there, and manifests itself in the ability of American brokers to secure the metal at a discount. When this discount passes a point just sufficient to cover freight, insurance and interest during transit, gold will be shipped to America. Now the amount of gold for which a thing will exchange is its price—the dollar being by law the exchange value of 23.22 grains of gold. This influx of gold to a country with free gold coinage, and not coming into response to any other demand, will swell the currency and, conversely, prices in general will rise. Assuming that

our supposed curtailment of imports is permanent, gold would continue to flow until prices in general changed, on both sides of the water and in opposite directions. Thus prices will go up in America and down in Great Britain, and English merchants will buy less in America in favor of their own home market. Since their purchases in America are our exports, it follows that our export trade will fall off. Which is what we wished to show.

The change in the prices we have just shown can have no permanent effect upon the internal commerce of either country, for an equal change in the price of everything simultaneously is not a change in exchange values generally.[1] But as between nations, the change is in an opposite direction and very materially affects the international trade. It should be noted that although the change in imports is permanent, the flow of gold induced is not permanent. It is only an initial flow, just sufficient to change the stocks of gold in circulation in the nations in question, to the critical point where changed prices will affect exports in like amount. After that, gold will return to its normal rate of flow.

Of course such a chain of cause and effect could never be illustrated by the actual course of events, for the reason that the "other things" we have imagined equal never are equal. This tendency to a decrease in exports might be entirely neutralized by a counter tendency such, for instance, as a rise in rents of American real estate owned by Englishmen living in England. Economically speaking these rents go to England as commodities, exports, real goods—although the recipient receives not any specific goods so exported, but a draft for gold, which in its turn is merely a draft for so much of any kind of wealth the holder may choose to select from the whole English market. The credit instrument representing the rent due is the effective cause of the flow of just so much real wealth from American shores. International payments are made in goods—real wealth, imports and exports.

This mechanism of trade is purely automatic. It bears the same relation to society that the involuntary functions of the body, such as the circulation of the blood, bear to the individual. Since a country does not transact its foreign commerce in its corporate capacity as a nation, but only as the sum of the transactions of its individuals and commercial houses—a national debit and credit account can not be periodically drawn up to show the total of all transactions. But such an account exists in effect as the sum of the accounts forming its parts. For a single year, or some short period of time, such an account would show an outstanding item or balance representing transactions not yet closed, but this would always be in the act of liquidating itself and would

[1] From 1870 to 1897 there was a gradual fall of about 50 per cent. in prices generally, but by 1910 about half of this had been regained. ("Principles of Economics," H. R. Seager, page 377.)

not accrue with the passage of time. It is not the balance of trade we are here concerned with. In the discussion of the balance of trade as in the discussion of the business of an individual, we are interested in a debit and credit account only to the extent that it shows closed transactions, for only then does it show what is being done as a regular thing, or in the long run. Indeed, the "balance of trade" as a question of "policy" can have significance on no other ground.

It appears from the foregoing that the first effect of checking imports of commodities is to substitute imports of gold, but it has also appeared that the substitution is temporary and is entirely shifted to a permanent checking of exports. This is to say that a nation in its corporate capacity can not force traders to deal in gold—it can not create a demand for gold, and the truth of this will become more apparent as we go on. But our attention must now be turned to the permanent or normal flow of gold. Is a balance of exports regularly liquidated by gold favorable?

This is the gold question. Under the conditions we are supposing, the entire excess of exports would be regularly paid for with an equivalent of gold imported. The "mercantile system" of the eighteenth century regarded the nations as competitors for the world's gold, and each country endeavored to increase its stock of gold indefinitely by attempts to restrict its imports and expand its exports. This idea is now generally abandoned, and among the foremost nations no conscious attempt is now made to attract gold. Indeed, in the case of a country like the United States such an attempt would be without reason, since the United States produces nearly one fourth the world's supply of gold, and is therefore normally a gold-exporting country. Whatever tendency there may be for export balances to become liquidated in gold, it is apparent from the statistics of the foreign trade of the United States that, in our country at least, the persistent balance in favor of exports *is not* paid for in gold. In the last twenty-five years (1890 to 1914 inclusive) the yearly balance for gold has fluctuated between favoring import and favoring export, ten times, while the net balance for the whole period is an insignificant amount (21 millions) favoring gold *export*. For the same period our balance of general trade favoring exports has steadily increased (excepting only the year 1893) to a net amount over *four hundred times* greater than the gold balance (9,358 millions). For any single year the greatest balance favoring a gold import occurred in 1898 when we could truly say that one sixth of our balance of exports, at least, was paid for with gold. But the figures in general are highly incomparable, and the most they show us is that the United States is not the example we are looking for—an example where "other things" are equal. As far as the gold question goes, our thesis remains—is a balance of exports liquidated by gold favorable?

The answer to this question will be in two parts. First, that in so far as the movements in such an exchange are free, obeying the natural law of supply and demand and each commodity moving from a point of lesser value to a point of higher value, the fact of gold being a principle in the exchange can be counted as neither favorable nor unfavorable. Being free bargainers, both parties must benefit in such an exchange or no exchange could take place. The party that sends the gold is better off, as well as the party who gets the gold. Thus a free and healthy exportation of gold would result in a country from such causes as an extensive gold-mining industry, an inflation of the currency with an increasing use of credit money, or from a decreasing demand for jewelry. This free or natural movement of gold, then, forms no part of the "balance of trade" discussions for gold so moving simply takes a place along with all other commodities forming the international trade.

The second part of our answer refers to a movement of gold that is not free, that is to a movement consciously instigated by a nation acting through its government. It was such a movement the "mercantilists" believed the successful nations succeeded in bringing about, draining gold from the less successful nations to themselves, in spite of the strong tendency to a counter flow which such an unequal distribution of gold would induce. They believed such a nation was thrifty in that it was saving wealth in the form of stored gold, to be reexchanged in time of war or stress, for useful commodities from other countries. This idea was probably a survival from times when interest-earning capital wealth was little known.

It is necessary to keep clearly in mind that we are not now discussing the free or natural movement of gold. Gold acquired with intention to save is not for use in coinage or any other way, for that comes through a natural demand. Gold stored in vaults serves no present use, but only the potential use contingent upon war.[2] It is capital wealth out of use —not drawing interest. For a nation to store wealth in this way it must buy gold with its commodities from other nations, paying an ever increasing premium as the foreign supply diminishes. Whatever the enactment which brings this about, it is in essence a tax upon the coun-

[2] The mind of the reader may here revert to the gold stored in the United States Treasury as security for paper money in circulation. The money problem properly forms no part of our subject, but for the sake of keeping proper proportions in the mind it may be well to state what this store of gold is. According to the report of the Secretary of the Treasury, there were one thousand eight hundred and fifty-eight million dollars in circulation and in the treasury, in the form of gold coin and bars, on April 1, 1913. Fifty-eight per cent. of this was security for gold certificates in circulation. If our balance of exports for the last twenty-five years had been paid for in gold, the amount would have been sufficient to increase this government stock sixfold, making it about eighty per cent. of the world's stock of gold.

try's own people who furnish the commodities with which to pay. In a sense they are paying interest on a debt before it is incurred—the debt of war. The people are saving only in the sense in which a miser saves, only because they have a certain soreness and fear towards other peoples. It is a superstitious regard for gold that no longer exists. A nation that hoards gold is making a sacrifice for something in which other nations are not trying to forestall her. To-day the process of saving is a creation of working capital goods, of wealth such as buildings, railways, machinery and so on. And in time of war such working wealth is quite as negotiable as gold, for a country at war may not only sell her securities for the necessaries she may immediately need, but so stable has the commercial world become she may undertake a public debt by issuing bonds for sale to other nations. The hoarding of gold is bad then, because working capital is better than idle capital, even in time of stress. Since this is now generally recognized, the point in favor of hoarding can not be granted even as a concession to "relative ethics." The nations of to-day are hardly more keepers of gold than are our rich men.

Therefore we say: A balance of exports induced for the purpose of storing gold for time of stress is unfavorable. Indeed, it seems to be doubtful if in these times such a balance could exist, but that in general it does not exist is sufficient warrant for the elimination of the gold question from the trade controversy by merging gold along with other commodities making up exports and imports. Gold moves first only because it has the least bulk and weight for a given value, but this gives it no distinction in kind over pig iron or any other form of wealth. The discussion is now reduced to that net balance of trade remaining after gold has been accounted for by including it in the inventory along with all other commodities.

Having satisfied ourselves that international payments are made in goods, exports and imports, of which gold is only one out of several hundreds, we have cleared the ground for the third part of our discussion, for an examination of the causes that make a "balance of trade" possible.

An international debit and credit account is not complete until every transaction affecting the transfer of wealth has entered into it. On broad lines such transactions might be divided into four classes, which would include them all. These are: exchanges, gratuities, loans and interest. Wealth may pass between two parties through free exchange, free giving, free lending or giving through coercion. The term interest is made broad enough to include everything from interest strictly speaking to tribute pure and simple. If we expand this to embrace in a more concrete way the larger items of present-day trade, we are able to frame up a general debit and credit account of one country with the rest of the world which is typified by:

ACCOUNT OF THE UNITED STATES WITH FOREIGN COUNTRIES

Debit	*Credit*
1. Imports (including gold).	1. Exports (including gold).
2. Interests on American securities and loans held by foreigners.	2. Interest on foreign securities and loans held by Americans.
3. Purchase of foreign securities, and loans to foreigners, by Americans.	3. Purchase of American securities and loans to Americans by foreigners.
4. Expense of Americans traveling abroad.	4. Expense of foreigners traveling in America.
5. Use of foreign vessels.	6. Remittances to immigrants by friends left at home.
6. Remittances by immigrants to friends left at home.	

A "favorable balance of trade" is considered to be a balance in favor of exports, an excess of exports over imports. Contrary to the general opinion, we propose now to show that such a balance is in reality not favorable.

Since the debit side of our international account from the point of view of the United States must always be substantially equal to the credit side, an excess of exports over imports implies an excess of items 2 to 66 on the debit side over times 2 to 6 on the credit side. That is to say, it implies an excess of one, any or all of them. Let us consider these in turn in the order given.

In so far as an excess of exports means that Americans are paying interest, dividends, rent, etc., to foreigners who own our resources and equipment, it is certainly unfavorable. This is tribute for which our foreign landlords return absolutely nothing. His draft is a draft upon our exports—economically he is paid with our exports. Many Englishmen own large farming tracts in America and these they divide up and let out to tenant farmers who render a very large part of the crop in rent. The owners for the most part remain in England, and thus there is a large export from America for which there is no return. The tribute exacted by Germany of France in 1871 caused a large excess of French exports over her imports. When Rome was mistress of the world, the wealth of the provinces was drained to her by taxes, tribute and rent for which no return was made. Her trade weighed heavily on the side of imports, yet it was a most "favorable" trade for her. We are cheerfully told that the picturesque Russian provinces in the Caucasus flourish under an export trade five times larger than the import. What does it mean? Probably that the greater part of the district is owned by Russian noblemen living in St. Petersburg, whose rents reach them through this heavy export trade. So in India, the "home charges" of an alien government and the remittances of alien officials cause a permanent excess of exports over imports.

In regard to item 3 let us suppose that Americans were to regularly

invest the same amount in foreign securities each year. At the end of the twentieth year, interest on twenty such annual investments would be due, and if the rate of interest was five per cent. or 1/20, the return to our country in interest would just balance the yearly purchase of securities. That is to say, item 2 on the credit side would just offset item 3 on the debit side. Or if this interest was compounded or more than compounded by an ever increasing annual investment by Americans, the annual purchase of foreign securities might indefinitely exceed the interest returns on them. But it is not only inconceivable that the annual investment should continually increase, it is inconceivable that it should remain constant. It is quite possible that any of these things might occur for one year or for a number of years, to be offset in other years by reverse flows, but that in the long run, or as a continuous process, our investments should regularly exceed the returns from them is impossible. The process of investing is a process of saving or creation of capital goods, and it is well understood that the amount of capital goods the world can use is limited. With the progress of invention this amount would increase and might increase rapidly, but could not increase indefinitely. Static periods and periods of decline must alternate with these rises, in which the capital in existence is sufficient and there is no saving at all. Mankind generally must forever produce and consume as a continuous process, but mankind generally can not save as a continuous process. The moment a certain limited and sufficient capital stock is brought into existence, saving must cease, for there is no gainsaying the principle that men seek to satisfy their wants with a minimum of effort. If mankind does not consume what can not be invested, then his wants can be satisfied with both less labor and less capital.

We conclude then that our annual purchase of foreign securities can not regularly exceed the interest returns from them, for if such were the case it would mean that Americans were gradually and surely acquiring the resources of the rest of the world at the same time they were receiving no net return.

Statistics showing the country's status in regard to items 2 and 3 are difficult to obtain. In *The Review of Reviews* (April, 1915) is a pertinent discussion of the billion-dollar export balance augured for 1915, and its relation to these "invisible factors" of international trade. We will quote from this in part, and in reading it the fact that our export balance has hovered around the half-billion mark for the last four years should be borne in mind. For the four years ending with 1914 the balance was 522, 551, 652 and 470 millions, respectively, so we may fairly say the normal excess is roughly half a billion dollars, and that the billion-dollar excess for 1915 is an abnormal excess induced

by the sudden call of Europe for war material. On page 403 of the review we read:

> . . . Sir George Paish has estimated that the item of freight and insurance charges is probably not more than $25,000,000. Competent statisticians have put our annual net return on indebtedness abroad at $300,000,000,—from which a deduction of $50,000,000 should be made for returns on American capital employed in foreign countries. Adding to these offsetting items the remittances to relatives and friends of the laborers, the statisticians figure that from the face figure of our favorable balance there should be deducted perhaps $500,000,000. On this basis we should for 1915 have a final net balance in our favor of more than half a billion dollars.
>
> How Will Europe Settle With Us?
>
> This does not however allow for the returns from foreigners of our securities which they have held and now sell back to us. The total of our securities held abroad is generally estimated to be about $6,000,000,000. It is certain that during the last few months a considerable fraction of this great total of bonds and stocks has been sold back to Americans, although the situation is too complicated to determine just how much. But at any rate it is difficult to see how Europe will settle her growing balance of indebtedness to America in any other way than by returning yet more of these securities. The summary way of settling the current debt would be by sending gold to New York, but in the first place the countries at war will not give it up, and in the second place it would not be desirable from our own point of view, as we have a plethora of gold at present.

It may fairly be inferred that the figures representing securities and returns therefrom are for normal conditions just before the war. It is most instructive to note that the statisticians show a substantial balance of the international debit and credit account for the normal years. They say about 500 millions should be deducted from the face figure of our favorable balance, and this lacks only one tenth of the average balance of trade for the four normal years. About one half of this they account for through our item 2, and for the rest items 5 and 6 are mentioned, although we suspect that item 4 for normal years was also included.

So much for what the figures show us as to normal or "running" conditions. That half of the billion-dollar balance not accounted for at the end of 1915 is the temporary balance which will be, must be, wiped out when we are able to average up the account with a few of the years yet to come. The transactions of 1915 are especially incomplete. But we can not insist too strongly that this temporary balance is not the so-called "balance of trade." The one is a balance about to be settled, the other is a running balance that will never be settled. Such a temporary balance can be counted as neither favorable nor unfavorable, for if the fact of having something due us is favorable, the payment of the due is a cancellation of the favor. No one will contend that it is favorable to a creditor that the debts he holds should never be

settled, yet only by such a system could his credit balance attain a maximum.

"How will Europe settle with us?" If we examine the debit side of our international account it appears that item 3 furnishes her only means in this time of her stress. Being too busy with war to make commodities for us, she must sell us her securities or sell us back our own securities or negotiate a loan from us. Each of these methods is at base a loan and on each Europe would have to pay interest.

Let us suppose that Europe has settled this half billion temporary balance by the transfer to us of the ownership of securities to that amount. And further let us suppose that after the war we are content to retain those securities and that Europe is unable to rebuy them. What permanent change has the war made in our trade balance and in whose favor is it? Clearly we shall be paying less interest and Europe more, to do which we must send her less goods and she send us more. Our balance of exports will be reduced or turned into an import balance and the movement will be in our favor. The heavy dealings in item 3 having ceased with the settlement of the abnormal temporary balance of trade, the large running balance in item 2 on the credit side will be offset by a large running balance in item 1 on the debit side. Europe can not forever settle this running debt of interest by continually incurring more debt or selling securities. If she is not to totally impoverish herself, she will sooner or later have to settle by swelling our imports with the tangible results of her labor.

An excess of exports may mean that there is much American travel abroad. Some say that it is a drain upon the United States for Americans to take their vacations abroad, because it gives the hotel business to Europeans instead of Americans. If this were true it would of course be an argument against the "favorable balance of trade" idea. As a matter of fact the travel abroad is neither a drain nor a benefit. If it gives hotel business to Europeans, it also gives an equal business to manufacturers of exports in the United States. What the travelers get in Europe is paid for with exports from the United States. Or we may look upon it in this way. In serving travelers, Europeans are taken out of other fields of production in which they would otherwise have produced for their own consumption. Their own consumption is now satisfied by producers in America, who export to the European market more than they otherwise would export, to just the extent of the drafts on America presented by our travelers at the European exchanges. Or, prospective American travelers produce wealth in America which they save, and consume later in Europe. What they nominally take with them is a letter of credit, but what they take economically is a certain quantity of exports which the letter of credit or other instrument releases from the American shores.

An excess of exports may mean that most of the ocean carriage is done in foreign bottoms, the excess being freight for carriage. Here again we see that if the business of carrying is taken away from us, an equal business of manufacturing the exports with which to pay the carriage is given to us. Any argument favoring the building up of our merchant marine is against the "favorable balance of trade" idea.

Items 4 and 5, then, do not seriously enter into the argument of the balance of trade, because it is easy to see that value is given for value received. They are the only cases of an export balance that is not unfavorable. But, be it observed, neither is their balance favorable.

Unlike the last two items we have discussed, remittances to friends are gifts for which there is no return. In so far as an excess of exports means that people in America are sending gratuities to Europeans, it is an economic drain upon America.

Our answer, then, to the question which has been the subject of this discussion—is a balance of trade in favor of exports favorable?—is an unqualified negative. We have seen that the export balance induced by travel abroad and the use of foreign bottoms is neither favorable nor unfavorable, and that the balance induced by the joint action of all other causes is unfavorable. Foremost among these other causes is the joint action of items 2 and 3 in which we have seen that item 2 must predominate. We have seen that the "gold question" might be used to support our negative did it have existence in fact, but we have also seen that in modern times its existence in fact is negligible. The parts of the problem which outweigh all others in considering the economies of a modern nation like the United States are to be seen in a survey of items 1 and 2. If we include the terms interest, dividends, rent, profits, under the single term interest, then we may say that an excess of exports means that a country pays more interest than it receives, that it is giving without receiving, that its resources are owned abroad when they might be owned at home.

Our conclusion is directly contrary to the current notion. So widespread and ingrained is the idea that an export balance constitutes a gaining trade, it is not sufficient for us to disprove it—we must account for it.

Our ideas regarding the actions of states and nations usually find their counterpart in our ideas regarding individuals. Probably the idea that it is more profitable to export than to import receives currency through the idea that it is profitable for a man's sales to exceed his purchases. This idea is a true one only when we have in mind a part of his life, his business life—only when we exclude from the term purchases, his purchases for consumption. We usually reckon profit or income upon money or credit outstanding, but this is a potential profit

which does not materialize until converted into goods or services for consumption. Now money or credit is merely a sign of uncompleted exchange, and a man's exchanges are not complete save to the extent that he has spent outstanding money or credit for goods or services for consumption. What we really have in mind when we say selling is better than buying is that a large excess of a man's sales over his purchases of capital goods is profitable *because* it is followed by a large purchase of consumable goods. Dealings in capital goods are profitable only *because* of this. The fallacy in transferring the idea to international trade lies in slurring over just this usually unexpressed qualification. With the man we are thinking of his uncompleted exchanges, while with the nation the "balance of trade" is an item in a balanced account of completed exchanges, and to that extent it is not a balance at all. With the man, his excess of sales is a credit, a lien upon the market, while with the nation her excess of exports is not a credit. That the trade balance is not a credit appears in startling form when we begin to look about for tangible evidence of credit. No one is puerile enough to believe that the nine-billion-dollar export balance of the United States, accrued during twenty-five years, is a lien to that extent upon the wealth of other nations and that either American citizens or the American government hold mysterious papers that have the power to recall nine billions of foreign wealth to our shores when we shall choose to have it. And if any doubts remain as to a certain store of gold, it is only necessary to remember that that nine billions is over and above all exports paid for with gold.

The current idea in regard to the balance of trade is closely associated with the doctrine of protection and the popularity of that doctrine is doubtless another source of the support the trade-balance idea receives. Those who believe in the protective tariff will believe in the "favorable balance of exports." In this connection its fallacies are obscured by the ease with which people are impressed with the concrete good or evil of an individual or small group of individuals, and the difficulty with which people are impressed with the general good or evil diffused over the whole community. It is doubtless true that protection and restricted imports are favorable to *some* Americans, but it can only be so at the expense of all other Americans, for we have seen that it is not favorable to the community as a whole.

But the question of the balance of trade here stands clear cut and apart from the tariff controversy, of which it forms an independent part. In the light of our demonstration it may fairly be said that of all popular fallacies it would be difficult to find another so groundless, so contrary to our simplest intuitions, and so readily capable of disproof, as the notion that it is more profitable to send things away than to take them in.

FIRE INSURANCE AND PROTECTION FROM FIRE

By MAYNARD M. METCALF, Ph.D., Sc.D.
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THE average annual loss by fire in America is over half as much as the cost of building the Panama Canal. This is an actual loss. Insurance, of course, restores nothing destroyed, but merely passes the hat for the benefit of the individual losers. The loss to the community is total. There are great benefits to the community from the payment of insured losses. It provides for the continuance of business with the least interruption and removes from individual losers much of the feeling of disaster and panic. This is of great moment to the community, but it does not repay to the community any of the loss actually incurred through the fire. It merely prevents still further loss from delayed recuperation.

But little thought has been given to the communal aspects of the economic system of fire insurance. It has been viewed chiefly from the standpoint of the individual. Insurance companies repay to individuals their actual losses and it is simpler for the individual to gain security against loss by fire by hiring an insurance company to carry his risks than it is for him to prevent loss from fire by building fireproof buildings. Indeed, experience has shown that "fireproof buildings" of the highest grade are not safe against great fires which have gained full headway and sweep in full force upon them from the outside. Fireproof construction of single buildings does not make them safe, if they are surrounded by burnable buildings. In the great Baltimore fire a heat of over 3,000 degrees Fahrenheit was generated, as was shown in three different regions when, after the fire, dentist's porcelains, fusible at that temperature, were found melted by the heat. The best fireproof construction does not protect a building from such temperatures. Marble crumbles; granite, especially if touched by water or its vapor, disintegrates; structural steel warps and twists.

After the Baltimore fire, there was in Baltimore much discussion of fire insurance and a little discussion of fire-fighting, but the author heard only one man mention the matter of fire prevention. Of course, from the standpoint of the prosperity of the country this matter of fire prevention was the one which should have received chief attention.

Two effective methods of protection against fires have been devised —first, fireproof construction and, second, automatic water sprinklers.

Fireproof construction is a safe protection against fires starting within the building, but not against major fires advancing upon the building from the outside. This device is the most expensive yet suggested, and to be effective it must apply to all buildings in a city. Berlin and Paris are pretty well protected in this way, but Tokyo, with its frail house construction and paper partitions, all of highly combustible material, would find this method of protection from fire of prohibitive expense.

Automatic water sprinklers have proved effective, reducing insurance costs by all the way from one third to nine tenths under different conditions. In the Baltimore fire, O'Neil's four-story department store stood in the direct path of the fire, but the curtains of water automatically thrown over its windows prevented the fire entering these and though the fire entered in three places beneath the roof the automatic sprinklers within extinguished it in each place. Indeed it was O'Neil's store, thus protected, which helped turn the fire eastward toward the little stream on whose banks it was finally checked. Water sprinklers are effective and are usually able to confine any internal fire to the room in which it arises, and similarly water curtains, outside windows and doors have proved efficient against fires approaching from without, in the few instances in which they have been tried. But the damage from water is a serious consideration and therefore automatic water sprinklers have by no means solved the problem of fire prevention.

There is need of experimental study of the whole problem of fire prevention—including fireproof construction and immediate extinction of fires at their inception. This subject has never had any real study worthy of the name, in this country or in any other. Roughly speaking, America's annual fire loss is a quarter of a billion dollars,[1] yet the total expenditure in the study of problems of fire prevention has been far less than this sum.

Why is this? Why has this subject been so neglected? The answer is very evident. The economic system of fire insurance, so greatly developed, has removed the individual motive for fire prevention, leaving only the communal motive to urge such protection. Individual security, reached through fire insurance, has made men thoughtless and careless about the loss to the community. It is even true that the collection of insurance serves as a motive for incendiary fires and this to an extent that is an important increment in each year's loss by fire.

The chief need is a government bureau to study experimentally problems of fire prevention in all its aspects. Prevention of forest fires

[1] Including Canada. This figure, of course, varies widely from year to year and considerably from decade to decade. If one of the main theses of this paper is correct and all fires in buildings could readily and inexpensively be suppressed before damage occurs, then a large portion of the cost of maintaining our enormous fire insurance system should be included as part of the "fire waste."

is a very different problem from that of prevention of fires in cities, and this again differs from the problem presented by scattered buildings. We have done something toward the prevention of forest fires, and the Forestry Bureau is giving this problem some good thought. We are doing practically nothing in the study of the problem of prevention of fires among buildings.

The problem is apparently not one of extreme difficulty. There is every reason to anticipate its satisfactory solution after adequate study. In the study of fireproof construction suitable for large public and commercial buildings, structures of many types should be built and burned and scientifically accurate knowledge obtained as to their behavior under conditions paralleling the real conditions of actual fires. Still more important is study of prevention of fires among inflammable buildings. The problem will not be solved until inexpensive methods are devised which will prevent any fire getting beyond the room in which it originates, however inflammable be the material of the building itself or of its furnishings, and the substance used in thus putting out the fire at its start must not be water but must be something that will not itself do damage to the most delicate fabrics. It is quite likely that automatic sprinklers throwing chemical fire-extinguishing substances may be found to meet the need. If it proved best to use substances injurious to human beings, automatic alarms could be used in all chambers or other inhabited rooms to rouse the occupants before the discharge of the deleterious chemicals. But discussion of such details is not appropriate here.

Suppose we should appropriate a quarter of a billion dollars, the amount of a single year's fire loss, to the organization and support of a Bureau of Fire Prevention, calling to the work of this bureau the three best chemists, the three strongest physicists, and the three keenest engineers in the world. How long would it be before they had found very inexpensive methods of protecting all buildings against fire, however inflammable their construction? The problem is childishly simple beside those which men of science are attacking daily and with success.

How absurd it is that we have fires to-day! They should long ago have become a thing of the past. On the Sunday when the great Baltimore fire broke out, the author was standing in the door of one of the churches after service, talking to the Reverend Dr. D'Aubigny, of Paris. When a hook-and-ladder wagon galloped past Dr. D'Aubigny asked, "What is that?" On being told it was fire-fighting apparatus on the way to a fire he said, "Oh! That is something I must see, an American fire. We do not have them in Paris." Paris, without serious study of fire prevention, has taken the expensive method of fireproof construction. We can well afford to use this same method for large public and commercial buildings, but we need also to install in all buildings, as

they now are, inexpensive devices that will at once extinguish any fire in the room in which it originates.

The economic system of fire insurance under private management, as it has developed, has suppressed individual initiative in fire prevention, has distracted attention from the real problem and has been the actual cause of postponing its solution for these many years. As developed, the system has proved one of the most colossal economic blunders, as it is one of the most absurd and childish. For thirty years the author has been interested in this subject, but only during the last five years has he seen any discussion of it, either scientific or popular, and never has he found any recognition of the utter economic absurdity of the present system of dealing with fire. There are a few glimmerings of awakening interest. Let us hope they prove an earnest of a genuine and adequate attack upon the problem.

THE BLACK DEATH, AND ITS LESSONS FOR TO-DAY

By Professor T. D. A. Cockerell
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WE are often told that the present European war is the greatest calamity the world has ever known, and as such, it paralyzes the minds of men, whose normal reactions are totally inadequate in the presence of such extraordinary conditions. Future students of the history of the twentieth century will read the chronicle with despair or boiling indignation, according to their temperaments, asking why, in heaven's name why, were those people so utterly incompetent to do the simple things which might have prevented the catastrophe? In many respects, there is little resemblance between the fourteenth century and the twentieth, and less between the bubonic plague and war; yet it may not be unprofitable to consider that other enormous European calamity, of the years 1348–9, and its effects upon the stricken populations.[1] Although the cause of death and loss was different, the results were in many respects similar, and if the attempts of our ancestors to deal successfully with the situation now seem to us amazingly futile, we may at least ask ourselves whether we are exhibiting any better judgment to-day. In the fourteenth century the microscope was of course unknown, and it was beyond the powers of the wisest man to learn anything about the *Bacillus pestis* or its communication to man by the rat flea. At the same time, the uncultured people of many times and countries had reached sound empirical judgments; and the beginnings of science in remote antiquity had promised something better than the dominance of unreasoning superstition posing as religion. Was it not a fact that the cult of the ruling classes had so imposed itself on the masses that for centuries the free action of the mind, in observing relations between cause and effect, had been inhibited? Is it not a fact to-day that a similar cult, that of the necessity and propriety of war, acts as a like inhibitor to those mental reactions which might otherwise clarify the atmosphere and make easy the way to peace? The problem of the fourteenth century was a terrific one, as is our problem to-day. Even a partial solution would have required the utmost exercise of all the wisdom available; but the point is, that then as to-day, men cravenly ac-

[1] My principal sources of information have been Dr. F. A. Gasquet's "The Great Pestilence" (London, 1893), and Mr. Edgar Powell's "The Rising in East Anglia in 1381" (Cambridge, 1896).

cepted as inevitable what might conceivably have been prevented. Petrarch in Italy thus wrote to his brother in June, 1348:

Alas! my beloved brother, what shall I say? How shall I begin? Whither shall I turn? On all sides is sorrow; everywhere is fear. I would, my brother, that I had never been born, or, at least, had died before these times. . . . When has any such thing been ever heard or seen; in what annals has it ever been read that houses were left vacant, cities deserted, the country neglected, the fields too small for the dead, and a fearful and universal solitude over the whole earth? Consult your historians, they are silent; question your doctors, they are dumb; seek an answer from your philosophers, they shrug their shoulders and frown, and with their fingers to their lips bid you be silent. Will posterity ever believe these things when we, who see, can scarcely credit them? We should think we were dreaming if we did not with our eyes, when we walk abroad, see the city in mourning with funerals, and returning to our home, find it empty, and thus know that what we lament is real. Oh, happy people of the future, who have not known these miseries and perchance will class our testimony with the fables. We have, indeed, deserved these (punishments) and even greater; but our forefathers also have deserved them, and may our posterity not also merit the same.

In France, in many places, two thirds or more of the population died.

In many towns, small and great, priests retired through fear, leaving the administration of the sacraments to religious, who were more bold.

At the hospital in Paris, for a long time more than fifty corpses were carried in carts to burial daily. The devout sisters of the hospital, like those of to-day,

worked piously and humbly, not out of regard for any worldly honor. A great number of these said sisters were very frequently summoned to their reward by death, and rest in peace with Christ, as is piously believed.

The chronicler (William of Nangis) notes disastrous after effects:

Alas! the world by this renovation [after the plague] is not changed for the better. For people were afterwards more avaricious and grasping, even when they possessed more of the goods of this world, than before.

Moreover, all things were much dearer; furniture, food, merchandise of all sorts doubled in price, and servants would work only for higher wages.

Philip VI. of France did indeed at the eleventh hour take a wise step. He called the medical faculty of Paris together to consult as to methods for combating the disease. Apparently the only advice the doctors could give was to avoid the sick. The king of Sweden, Magnus II., was more in accord with the spirit of the times. He issued a preparedness proclamation, advising every one to abstain on Friday from all food but bread and water, "or at most to take only bread and ale," to walk with bare feet to church, and to go in procession around the cemeteries carrying the holy relics.

The approach of the plague to the shores of England soon caused

apprehension. The Bishop of Bath and Wells sent letters through his diocese ordering processions every Friday in each collegiate, regular and parish church, and granting an indulgence of forty days to all who, "being in a state of grace, should give alms, fast or pray, in order, if possible, to avert God's anger." The coast of Dorsetshire seems to have been the first part infected, but the disease spread rapidly through the country. Gasquet remarks: "it is curious to observe how closely the epidemic in this country clung to the rivers and water-courses," a suggestive observation now that we know the connection of the disease with rats. "The mortality," says the same writer, "attacked the young and strong especially, and commonly spared the old and the weak"—its effects here being comparable to those of war. Just as to-day, Oxford and Cambridge were depleted of their students; and although to-day we honor and admire the many hundreds of young men who have left their colleges to fight for their country, we may no less than the men of the fourteenth century deplore the deaths of so many of those who were expected to lead the intellectual forces of the nation. In the earlier period, when the universities existed primarily for the education of the clergy, the loss fell upon the church, which suffered in many ways; to-day the injury will necessarily be more general, and if less conspicuous, no less serious. Dr. Gasquet, in a most interesting and instructive final chapter, sums up "some consequences of the great mortality." These consequences were good and bad, but of tremendous importance in either case. From the Norman conquest up to the middle of the fourteenth century, the nobility and gentry conversed in French, and their children were taught in that language. A schoolmaster named Cornwall introduced English into the instruction of his pupils, "and this example was so eagerly followed that by the year 1385, when Trevisa wrote, it had become nearly general." This change, the author suggests, could never have been effected had not the plague carried off so "many of those ancient instructors," that the opposition to it could be overcome. Thus was the English of Shakespeare made possible.

In architecture, the effects of the epidemic are still visible to-day. In many cases buildings which had been begun were never finished; or if finally completed, it was in another style which had since come into vogue. There is similarly a break in the development of stained-glass manufacture; first an interval, and then the resumption of work showing a change of style.

The tremendous shock to people's minds and habits produced a reaction which, in the long run, led to good results. But the disorganization let loose much evil, and Gasquet is obliged to state:

> It is a well-ascertained fact, strange as it may seem, that men are not as a rule made better by great and universal visitations of Divine Providence.

It was noted of the great plague in the reign of the Emperor Jus-

tinian, that "whether by chance or Providential design it strictly spared the most wicked," and it was "the universal testimony of those who lived through" the period of the Black Death, "that it seemed to rouse up the worst passions of the human heart, and to dull the spiritual senses of the soul." Nevertheless the author is able to present a better side, and his words are so eloquent and so significant for modern times that I quote at length:

> In dealing with this subject it is difficult to bring home to the mind the vast range of the great calamity, and to duly appreciate how deep was the break with then existing institutions. The plague of 1349 simply shattered them; and it is, as already pointed out, only by perpetual reiteration and reconsideration of the same phenomena that we can bring ourselves to understand the character of such a social and religious catastrophe. But it is at the same time of the first importance thoroughly to realize the case if we are to enter into and to understand the great process of social and religious reedification, to which the immediately succeeding generations had to address themselves. The tragedy was too grave to allow of people being carried over it by mere enthusiasm. . . . It was essentially a crisis that had to be met by strenuous effort and unflagging work in every department of human activity. And here is manifested a characteristic of the middle ages which constitutes, as the late Professor Freeman has pointed out, their real greatness. In contradistinction to a day like our own, which abounds in every facility for achievement, they had to contend with every material difficulty; but in contradistinction, too, to that practical pessimism which has to-day gained only too great a hold upon intelligences otherwise vivacious and open, difficulties, in the middle ages, called into existence only a more strenuous and more determined resolve to meet and surmount them. . . . Many a noble aspiration which, could it have been realized, and many a wise conception which, could it have attained its true development, would have been most fruitful of good to humanity, was stricken beyond recovery. Still no time was wasted in vain laments. What had perished was perished. Time, however, and the power of effort and work belonged to those that survived.

Subsequent to the plague of 1348–9, and its recurrence in 1361, the conditions of labor were greatly altered, in ways presenting an interesting parallel to what we see going on to-day. Mr. Edgar Powell, in his account of "The Rising in East Anglia in 1381," takes up this phase of the subject, giving many details. In the rural districts great numbers, in some places nearly one half, of the population had been swept away, and naturally the supply of labor was extremely scarce. This led to a demand for higher wages, but the landowners, quite unable to adjust themselves to the new conditions, resisted by every means in their power. They even secured legislation establishing—not the minimum wage we hear so much of to-day—but a *maximum* wage, with punishments for all those who gave or received more. The principal result of this was to exasperate the working classes, who were further infuriated by the severe penalties which the law permitted; even, if the prosecuting individuals desired, extending to branding the foreheads of those convicted. Added to all this, came the heavy burden of the poll-tax, which was the final

and immediate cause of revolt. New ideas of liberty, fraternity and equality, the germs of our latter-day socialism, filled the air; and those who began by rebelling against an excess of injustice, now looked forward to a veritable heaven upon earth. William Morris, in his "A Dream of John Ball" (1890), has given us an idealized version of the rebellion, centering about the personality of that "rascal hedge-priest" John Ball, who seems to have chiefly represented the idealism and intellect of the movement. "Yea, forsooth," Morris supposes Ball to say, "once again I saw as of old, the great treading down the little, and the strong beating down the weak, and cruel men fearing not, and kind men daring not, and wise men caring not; and the saints in heaven forbearing and yet bidding me not to forbear; forsooth, I knew once more that he who doeth well in fellowship, and because of fellowship, shall not fail though he seem to fail to-day, but in days hereafter shall he and his work yet be alive, and men be holpen by them to strive again and yet again; and yet indeed even that was little, since, forsooth, to strive was my pleasure and my life."

The revolt was crushed, and had it not been, it could not have accomplished its proper purpose. Time was needed for that, but the old condition of affairs never quite returned, and much of what we cherish most to-day had its remote beginnings in that apparently fruitless struggle. After the present war, in the readjustment which must necessarily take place there will be opportunity and necessity for reform Will it be possible to approach the problem with an eager desire to make the best of the situation, or will those in power stubbornly resist every fundamental change? In particular, can we throw off the burden of militarism by appealing to the intelligence and good-will of mankind; or will the populace, finally goaded to desperation, be driven to revolution? As in the fourteenth century, we are borne on the crest of a wave which we can not stem; up to a certain point, we are compelled by the course of events,—but it will make all the difference in the future whether we now approach our problems intelligently or with ignorance and prejudice. A great catastrophe, whether plague or war, breaks many links with the past, and gives the surviving generation new power and new opportunity. Thus, to an unusual extent the deeds of that generation affect those to come, and heavy is the responsibility if a false start is made.

An apparently good authority (Hecker) estimated that in the fourteenth century the bubonic plague destroyed about twenty-five millions of persons, with the various results briefly indicated above. Yet historians have been so blinded by the political and military aspects of history that they have been unable to sense the significance of these tremendous events. As Gasquet remarks,

Judged by the ordinary manuals, the middle of the fourteenth century ap-

pears as the time of England's greatest glory. Edward III. was at the very height of his renown. The crushing defeat of France at Crecy, in 1346, followed the next year by the taking of Calais, had raised him to the height of his fame. . . . It is little wonder, then, that the Great Pestilence, . . . coming as it does between Crecy and Poitiers, and at the very time of the creation of the first Knights of the Garter, should seem to fall aside from the general narrative as though something apart from, and not consonant with, the natural course of events.

Consequently Hume and others "dismissed the calamity in a few lines," and even J. R. Green, who had a more intelligent grasp of historical sequences, "deals with the great epidemic in a scanty notice only as a mere episode in his account of the agricultural changes in the fourteenth century." Will the historians of the days to come record the present era as one of glorious victories and splendidly dominant monarchs; or will they know what those now engaged in battle can not fully know, that the masses on both sides had a common cause and a common enemy?

RESOURCES IN MEN

By Brigadier-General H. M. CHITTENDEN, U.S.A. (ret.)

SEATTLE, WASH.

THE war has progressed far enough to convince most people that its outcome is no longer dependent upon the state of preparation before it began, but rather upon the future endurance of the belligerents. This endurance relates, first, to resources in men, and, second, to resources in wealth. It is proposed in this article to analyze with some care the question of resources in men, for there can be no doubt that the struggle has reached a stage with some of the belligerents where this question is causing anxiety.

To begin with, what proportion of the total population is available for military service? That depends both upon the age limits and the physical standard in force in the country considered. When there is a superabundance of material, very rigid qualifications are likely to be insisted upon. Thus in our country in time of peace the age limits are 21–35, extending to 18 with the consent of the parent or guardian; but the requirements are so strict that, even within these limits, which cover only the most robust period of life, three out of four applicants on the average are rejected.[1]

The standard military age the world over has long been 18–45, the upper limit being at the forty-fifth birthday. It is universally recognized that approximately two fifths of the total population fall within these limits. The exact figures for certain countries and censuses are exhibited in the following table and shown graphically on the accom-

PROPORTION OF POPULATION BETWEEN SPECIFIED AGE LIMITS

Specified Age Limits	England and Wales, Census 1911	Germany, Census 1910	France, Census 1906	United States, Census 1910
0 to 14 inclusive	30,637	34,051	26,021	32,098
15 to 59 inclusive	61,327	58,073	61,398	61,141
60 and upward	8,036	7,876	12,581	6,761
For all ages	100,000	100,000	100,000	100,000
18 to 44 inclusive	42,406	39,727	40,190	43,100
17 to 49 inclusive	47,756	46,700	47,901	49,900

[1] Probably this is not a true criterion of the military availability of the population, for the reason that in this country, where such high wages prevail, it is generally men of defective working ability that seek enlistment.

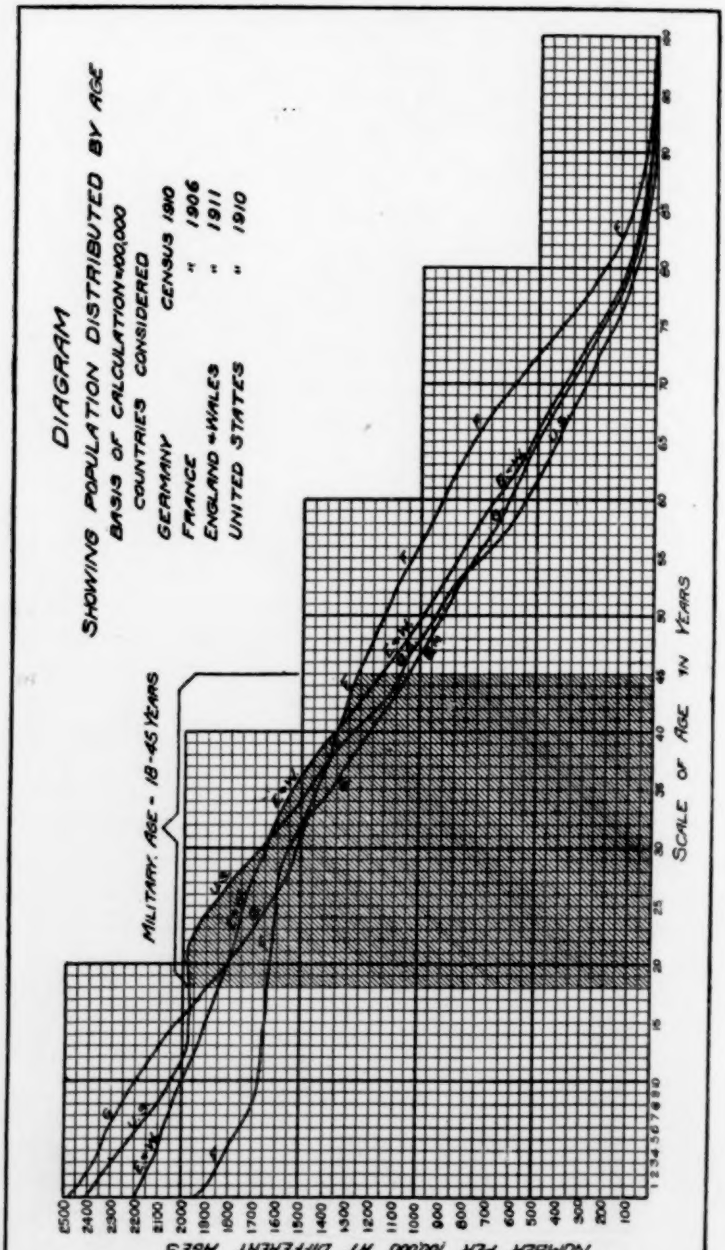


DIAGRAM
SHOWING POPULATION DISTRIBUTED BY AGE
BASIS OF CALCULATION = 100,000
COUNTRIES CONSIDERED
GERMANY CENSUS 1910
FRANCE " 1906
ENGLAND & WALES " 1911
UNITED STATES " 1910
MILITARY AGE - 18-45 YEARS
SCALE OF AGE IN YEARS
NUMBER PER 100,000 AT DIFFERENT AGES

panying diagram. For purposes of comparison of different countries, both the table and diagram are based upon a population of 100,000. To pass from these to the actual figures for any country, multiply the quantities taken from the table or diagram by the total population divided by 100,000. The age limits, 17–50, are separately given in the table because of their actual adoption by the Confederate States in the American Civil War.

The graphic presentation of these results is instructive and easily understood even by the uninitiated in that method of illustration. To find the proportion of 100,000 at a particular age for any of the four countries, look for the age in the scale at the bottom of the diagram. Then follow the corresponding vertical line until it intersects the irregular line, or curve, for the country considered. Next follow the horizontal line through this point of interesection to the vertical scale on the left and read off the corresponding number. The area of the diagram bounded by the vertical and horizontal scales and by any one of the curves represents 100,000 population; and the shaded area the proportion within the age limits, 18–45.

We may now make clear what puzzles a great many. We think of the immense numbers born each year, or arriving at military age, and it seems as if the supply must be rapidly increasing. We do not so readily see the annual decrease which offsets it. Look on the diagram at the vertical line representing age 17. Next year that will pass over into 18, the military age. But at the same time the line 18 has passed into 19, slightly shortened, however, through the deaths that have occurred during the year. In like manner 19, similarly shortened, has passed into 20. So on through the whole series until finally 44 passes into 45 and out of the military age altogether. With constant conditions as to the birth and death rates, the sum of the numbers by which the several years are shortened by death and of the numbers passing over into 45, or out of the military age, exactly equals the numbers passing in from 17 to eighteen. Thus it is a continuous process of gain and loss, the balance remaining constant for a fixed condition of the population.

Particularly interesting are the characteristic features of the population movement in different states, as disclosed by the diagram. The high birth rate of Germany and the low birth rate of France are clearly indicated. Germany is a nation high in its percentage of youth; while France is high in the middle and old age periods. England falls between. The United States begins with a curve similar to that of Germany; but from about the age of 13 it ceases to decline and continues practically horizontal for the next ten years, which places it, at 23, far above any other country. This is entirely due to the influx of immigrants, which is strongest in the ages 15–30, with a maximum at 21–25. The reverse effect would undoubtedly be apparent in countries from which there is a proportionately heavy emigration.

The proportion of population within the age limits 18–45 being about 40 per cent. of the total, and about half (in Europe a little more than half) being women, there remain one fifth men, as already pointed out. But not all of these are available for military service. Some are physically unfit and some have to be retained at home to do the necessary work. What these exemptions amount to depends upon the physical standard adopted, and upon the requirements of home service and the ability of the non-military population to perform it. In the Confederate service at the close of the Civil War a most rigid draft was enforced. In a white population east of the Mississippi, of about 3,600,000 (Negroes were not taken into the service to any appreciable extent) the number of exempts which had to be allowed between the ages 17 and 50 was 87,863, or about 10.3 per cent. of the male population within these limits.

RESOURCES IN MEN

Name of Country	Latest Estimates of Population	18 to 45 Years, 16 %	17 to 50 Years, 18.8 %	Arbitrary, 10 %
Germany	(1916) 67,812,000	10,850,000	12,740,000	6,718,000
Austria-Hungary	(1910) 51,814,000	8,290,000	9,741,000	5,181,000
Turkey	(1910) 20,000,000	3,200,000	3,760,000	2,000,000
Bulgaria	(1914) 4,750,000	760,000	873,000	475,000
Total	144,409,000	23,1000,000	27,123,000	14,374,000
Russia	(1912) 173,356,000	27,737,000	32,591,000	17,336,000
United Kingdom	(1913) 46,185,000	7,390,000	8,683,000	4,619,000
France	(1911) 39,602,000	6,336,000	7,445,000	3,960,000
Italy	(1911) 35,239,000	5,638,000	6,625,000	3,524,000
Belgium	(1912) 7,571,000	1,211,000	1,423,000	757,000
Servia	(1914) 4,547,000	732,000	855,000	455,000
Montenegro	(1914) 516,000	83,000	97,000	52,000
Colonies	25,000,000	4,000,000	4,700,000	2,500,000
Total	322,016,000	52,127,000	62,419,000	33,203,000
Roumania	(1914) 7,508,000	1,201,000	1,412,000	751,000
Greece	(1914) 4,821,000	771,000	926,000	482,000
Total	12,333,000	19,720,000	2,338,000	1,233,000

The figures in column 2 are from the Almanach de Gotha, except those for the Balkan States, which are from the Statesman's Yearbook. They are given to the nearest thousand only. The Belgian, Serbian and Montenegrin population is nearly all not available. The estimate for "Colonies" is purely arbitrary, but it would be manifestly wrong to make the basis that of actual population.

For the age limits 18–45 the percentage may have been as low as ten, but this must be considered as a minimum under any circumstances. It would ordinarily be considerably higher. Most of the exempts in the Confederate service were such as were physically or mentally unfit, as negro slave labor made it unnecessary to retain many white men for work

at home. But this exceptional resource is now nowhere available, and an additional percentage must therefore be deducted. What this should be it is difficult to say, but it is certainly not less than ten per cent.

It thus results that the male population of military age (20 per cent. of the whole) must itself be reduced by at least 20 per cent. This leaves 16 per cent. of the total population between the ages 18 to 45. A similar deduction gives 18.8 per cent. for the age limit 17 to 50. These figures must be considered maxima which could be realized only under the stress of an emergency so great as to sweep into the ranks practically every available man. In the Confederate service the age limit 17–50 was undoubtedly exceeded, and it was a common saying in those days that the South was robbing both the cradle and the grave to replenish her vanishing armies. Even in the northern army there were enrolled over 100,000 boys of fifteen years or under. Many authorities consider that 10 per cent. of the total population is the practical limit available for the recruitment of armies. The application of these percentages to the several belligerent states is shown in the table on p. 90.

Right here it is important to repeat the caution given in a preceding paragraph that the annual increments to the military age do not mean corresponding increase in the number of men available. How easy it is to make a mistake here is shown by the following recent utterance in one of our most widely read and authoritative periodicals:

> Germany is growing at the rate of a million a year. That means at least 500,000 fresh soldiers coming into manhood annually.

Quite evidently, from what we have shown, it means nothing of the sort. The population curves (see diagram) are practically the same for any two consecutive years. Applying these to the actual population of any country in which the population is increasing (of course there is no increment in a stationary population like that of France) it will be found that the annual increment is distributed throughout the whole period of life in practically the same proportion as shown in the diagram. This gives a maximum of 16 per cent. available for duty between the limits 18 to 45. Applied to the assumed annual increase in German population of one million (it is actually a little less than that) we have 160,000 instead of the 500,000 assumed by the author quoted, and even this is probably too great.

Thus far we stand on comparatively sure ground. But we find ourselves on very slippery ground the moment we attempt to determine the extent to which the present war is drawing upon these resources. The best estimates that can be made are largely guesses. We shall here make two arbitrary assumptions which we consider maxima and minima and somewhere between which the actual facts probably lie. Assume

first that the maximum number of men under arms and available for duty when the war is at its height is, for the Allies, 8,000,000 men, and for the Central Powers, 6,000,000. Assume also that the annual losses from all causes (killed, wounded, missing, etc.) will average for the Allies 3,000,000, and for the Central Powers, 2,500,000. Under these assumptions the draft on available resources, in order to maintain maximum strength and make up for losses, will be at the end of the second and third years of the war:

For the Allies, 14,000,000 and 17,000,000.

For the Central Powers, 11,000,000 and 13,500,000.

Now let us assume that the maximum strengths will be, for the Allies 10,000,000, and for the Central Powers 8,000,000; and the average annual losses, for the Allies 4,000,000 and for the Central Powers 3,000,000. The figures at the end of the second and third years will then stand:

For the Allies, 18,000,000 and 22,000,000.

For the Central Powers, 14,000,000 and 17,000,000.

Comparing these figures with the footings in the table of "Resources in Men," the drain upon these resources, even under our maximum assumptions, is seen not to be excessive. But this way of putting it is possibly too favorable to the Allies. If their resources could be pooled so as to be available in as complete a sense as are those of the Central Powers, the showing would be more accurate. But this is not the case. The resources of France, for example, will begin to give out while those of Russia are still not taxed to a third of their capacity. Yet the great Slavic reservoir of men is not available for the battlefields of France. Whether it can accomplish its full purpose by bringing pressure to bear upon the eastern front may be open to doubt; but that nevertheless is the rôle which it must play and it must evidently continue to be a part of the burden upon Great Britain and France to help furnish the funds for equipping the hosts of their great eastern ally.

It will be observed that in our estimates we have made no allowance for a possible "robbing of the cradle and the grave," as in the case of the Confederacy during the American Civil War. The additional resources which might thus be made available are quite beyond our powers of estimate. But our study does clearly indicate that the one danger which either side has least to fear, if the present line-up continues, and if measures are made effective for getting men into the ranks, is a deficiency of fighting men. If the crushing weight of either side could be brought to bear against any one unit of the other, as actually happened in the case of the Central Powers against Belgium, Serbia and Montenegro, the situation, so far as such units are concerned, would be very different. But at present that seems not very likely on any large scale. The whole resources are being brought into play over a wide front and the likeli-

hood of separate exhaustion of any portion is rather remote. Nevertheless prophecy is too hazardous to indulge in. It is safe to say this, however, that the strength of either side—or its weakness—is to be measured more directly by its ability in organization, in the production of munitions, and in the efficient marshalling of resources than in the number of men available. This matter of organization goes altogether beyond the mere creation and handling of armies; it is coming to embrace the whole industrial life of the state itself. It has enabled the Teutonic Alliance, with less than half the resources in men of their opponents, to make decidedly the better showing thus far.

WHO PAYS FOR THE PANAMA CANAL

By C. E. Grunsky, Eng.D.

ONE TIME MEMBER ISTHMIAN CANAL COMMISSION

HAD the Panama Canal been constructed by private enterprise subject to rate regulation by the United States, it is safe to say that the owner would have been allowed earnings that would cover operating expenses, including the requirement of replacing all parts thereof as they go out of use, and also a reasonable return on the capital invested in the enterprise. There would have been no allowance for amortization of the capital unless in the special case of a term franchise and a purpose on the part of the United States to acquire the canal during the life of the franchise. On the assumption of perpetual ownership by private parties there would be no sense in allowing the investment to be reduced unless the United States should desire to become a partner in the enterprise to the extent of such reduction.

The American people, as owners, are accountable to the whole world for the management of this enterprise and should make themselves familiar with the fundamental principles which should control the establishment of the canal tolls.

Has the United States constructed the canal for profit?

Has the United States constructed the canal as an investment which is to yield a reasonable return on its cost?

Has the United States made the investment in the canal as a temporary investment which it will endeavor to recover from those who use the canal?

Can the United States afford to make such investments for the benefit of commerce without recovering interest on the investment?

The answers to these questions will guide the economist who fixes the tolls, and will give him his starting point.

If the net earnings of the canal, that is, earnings in excess of operating expenses, are sufficient to meet interest on a bonded debt equivalent to the cost of the canal and enough surplus to return to the United States in a fixed time, as, for example, 100 years, the cost of the canal, then, at the end of this time the United States will no longer be out of pocket anything for canal construction. The nation will be in the same position as though some one had made it a present of the canal. During this time at some regular or irregular rate those who have travelled through the canal, and those who have purchased the goods transported through it, will have returned to the treasury of the United States the entire investment. The amount of the annual profit will be the factor

which in the last analysis will determine the time when the investment is fully amortized. It may appear to be good business to let the canal thus pay for itself, but there is another side to the question.

If the earnings of the canal are so regulated that they will meet operating expenses and interest on a bonded debt equal to the cost of the canal and no more, then the United States will be in the position of having loaned to commerce, as a permanent investment, a sum equal to the canal cost. The United States will be receiving interest on this investment. Apart from the benefits resulting to the country indirectly, the United States will be no better and no worse off financially than if the canal had not been built.

If, as an extreme case, it be assumed that the earnings are such that they will just meet operating expenses (including all replacement requirements) but nothing for interest and sinking funds, then the United States will be in the position of having donated for the benefit of the world's commerce a sum equal to the cost of the canal.

When a highway is constructed, when a harbor is dredged, when such works as the breakwater at San Pedro Bay, the breakwater at the mouth of the Columbia River, the South Pass at the mouth of the Mississippi River, the Ambrose Channel at New York harbor, and the many lighthouses on our ocean coasts, on the lakes and rivers, are constructed at government expense, the commerce which is benefited thereby is not taxed. The cost of these works is willingly borne by the country at large. There is no sinking fund to be provided. No interest on the investment is expected. Even the operating expenses come from the national or state treasuries. All this finds general acceptance as a matter of course. It is economically sound. The indirect return to the country is many times greater than the cost which has been incurred in the construction of such improvements, and no one objects to the wise expenditure of public funds for these purposes.

In what respect then does the Panama Canal as an aid to commerce differ from these works which are nearer home? In this only, broadly speaking, that in the case of all these other improvements, there is United States territory at one end, at least, of each business transaction which they facilitate, while the Panama Canal not only facilitates business between our own ports and between our country and foreign countries, but, also, in no small measure, the business carried on between foreign countries.

This fact needs no elaboration. It is patent. And due to this fact a different fundamental principle should find application than has so generally and properly been applied to the improvements which our nation and the several states and municipalities have made and are constantly making for the benefit of the public. This does not mean that we are to exact the "whole pound of flesh"—that we are to make

the traffic pay for the canal. By no means. We should not even ask the traffic to return to us any part of the canal cost, but we may, in all fairness, ask for a small interest return in order that foreign shipping, engaged in trade between foreign countries, may not be relieved entirely of a fair contribution toward interest on the money invested in the canal.

In so far as the business having any United States port at one end is concerned, it would be not only proper, but desirable, to have the tolls arranged with a view to making no interest return upon the invested capital. Let the whole country, every section of which profits directly or indirectly, stand this part of the operating cost. But in the case of traffic through the canal with foreign ports at each end of the business transaction the matter is different, and whether the ships be under a foreign or under the American flag, the tolls should be somewhat higher, estimated perhaps as they would be estimated if the entire traffic through the canal were to yield a low interest rate on the investment.

Professor Emory R. Johnson, in his report as special commissioner on Panama traffic and tolls, addressed to the Secretary of War in 1912, passes lightly over these questions. He accepts the principle that "business prudence and political wisdom demand that the canal shall be commercially self-supporting, provided revenues large enough to enable the canal to carry itself can be secured without unwisely restricting traffic" and says "the annual revenue ultimately required to make the canal self-supporting will be about $19,250,000." In this sum there are included $3,750,000 for amortization of the government's investment in the enterprise. Professor Johnson says:

In deciding what tolls shall be charged for the use of the canal, the fundamental question is whether a system of charges can be devised and levied that will ultimately yield about $19,250,000 per annum without unduly burdening American trade and without seriously limiting the ability of the canal to compete for traffic against the routes via the Straits of Magellan, the Cape of Good Hope and the Suez Canal.

It is gratifying to find that in a later paper read before the International Engineering Congress in 1915 by Professor Johnson, there is an apparent modification of the view expressed by him in 1912. He says:

The government should resist this pressure [to lower the rate of tolls] until the revenues derived from the canal cover the annual operation and maintenance expenses and the interest on what it cost to build the waterway.

This is sound doctrine, if we accept interest to mean interest at a low rate, except only for the fact that the government might do well to give way to the pressure long before interest on cost is fully covered by the earnings.

Professor Johnson in his recent paper points out that if the rate of

tolls now established be maintained for ten years and if subsequent reduction be made with caution, it will be possible for the American people to secure revenues from the canal that will ultimately return to the United States treasury the sum that has been invested in the waterway. He leaves us in doubt, however, whether he distinctly advocates this course, saying only that

> This can be done without restricting the usefulness of the canal, and if this policy is followed out it will be possible for the United States, with less burden to the taxpayers of the country, to construct other needed works.

Against any policy looking to the recovery of the cost of the canal out of its earnings there should be strong protest. It can not be carried out without materially restricting the usefulness of the canal. It would be unwise and unfair to those who use the canal. It would put this government into the undesirable position of having entered upon a commercial venture for profit with unnecessary restrictions upon the world's commerce.

If Professor Johnson's prediction be accepted as fairly dependable the canal tolls as now fixed are too high and should be reduced at the earliest possible moment. It should be assumed that the commerce of the present day should be relieved from any unnecessary burden fully as much as that of the future.

If the cost of the canal must some day be returned to the United States by the users of the canal, let this occur, not in this generation, but in the future when the larger traffic will not feel an added charge as a burden.

In giving expression to these views no consideration has been given to the fact that for military purposes alone the canal is worth to the United States all that it has cost. There is special reason therefore for making the traffic charges lower than would be done if the construction of the canal had been determined by commercial considerations alone.

The proposition, sometimes advanced, that consideration should be given to the transcontinental railroads when canal tolls are fixed is without special merit. Their business is a matter apart. They are entitled to and will get adequate protection, but should not look to a high canal tariff as an aid in increasing their business. There is no obligation on the part of the American people to reduce canal traffic for the benefit of the railroads and their users, and it would be a mistake on the part of the railroads to make any such claim.

THE PROGRESS OF SCIENCE

ENGINEERING EXPERIMENT STATIONS IN THE LAND GRANT COLLEGES

On July 2, 1862, President Lincoln approved the act establishing the Land Grant Colleges of Agriculture and the Mechanic Arts, and on March 3, 1863, he approved the act incorporating the National Academy of Sciences. When the nation was stricken down with civil war it sought relief in science, on the one hand, establishing institutions for the scientific education of all the people in the arts of peace, on the other hand, recognizing exceptional merit in science and making the most distinguished men of the country the advisers of the government.

Now when the world is again infected by war more terrible than can be imagined in this one great nation which has escaped, we are naturally driven to think of "preparedness," and it will be well if this movement can be directed to making the nation strong through education and scientific research. At least three bills are before the Congress which are more important for the welfare of the country and its defense from foreign aggression, should that ever become necessary, than any enlargement of the army and navy. These bills would establish a national university, extend secondary education in industry and agriculture, and establish research stations for engineering at the colleges of agriculture and mechanic arts.

A national university at Washington, holding the same position toward the state and privately endowed universities as these hold or should hold to the colleges and schools of each state, would correspond with the establishment of the National Academy of Sciences during the civil war, but could be made far more effective in its influence on research and on the efficient conduct of the departments of the government.

The Smith-Hughes bill provides for the promotion of the vocational education of boys and girls of high-school age through cooperation of the nation and the states. There is appropriated for the first year $1,700,000 with an increment each year for eight years on condition that each cooperating state shall appropriate an equal sum. In the first year the sum of $200,000 is for administration and investigation, $500,000 for training teachers for vocational work, and $1,000,000 for payment of teachers, equally divided between agriculture, on the one side, and trade, home economics and industry, on the other.

Of special interest to scientific men is the Newlands bill establishing research stations in engineering, corresponding to the existing agricultural stations in the colleges of agriculture and the mechanic arts. These land grant colleges and their agricultural research stations have been of incalculable value to education, to agriculture, to the states and to the nation. They have been largely responsible for the establishment and development of the state universities. The land grant colleges and the institutions of which they are a part received in 1914 from the United States $2,500,000; from the states and from other sources over $30,000,000. They have 9,000 instructors and 105,000 students.

By the Hatch act of 1887 and the Adams act of 1906 the sum of $30,000 a year is appropriated for research in agriculture in the experiment stations. The colleges have more students of mechanic arts than of agriculture, but there is no similar provision for re-

search in the mechanic arts and engineering, and the sciences, such as physics and chemistry, on which they are based. The agricultural interests have always had great influence on legislation and in this case they have led the way. It is to be hoped that research in the engineering sciences will now be equally encouraged by the passage of the Newlands bill, which appropriates $15,000 to each state and territory for conducting investigations in engineering and publishing the results.

Some scientific men may believe that more could be accomplished by the establishment of one great research laboratory or by granting the money only to institutions already distinguished for their contributions to science. There is, however, much to be said for initiating investigation in fifty widely scattered centers where work is already being done in agricultural science. It brings the value of research to the attention of the students of the college and the people of the state, and each station has the possibility of great development. In any case the passage of the bill as it stands is the most feasible method at present to extend research and will forward rather than interfere with other methods.

RESOLUTIONS OF THE COMMITTEE OF ONE HUNDRED

The Committee of One Hundred on Scientific Research of the American Association for the Advancement of Science has given consideration to the Newlands bill and has passed the resolutions which follow:

WHEREAS the applications of science have made democracy possible by so decreasing the labor required from each that equal opportunity can be given to all;

WHEREAS in a democracy scientific research, which is for the general benefit and can not usually be sold to individuals, must be supported by the public;

WHEREAS a combination of national and state support and control is desirable in education and in research and its value has been fully proved by the land grant colleges of agriculture and the mechanic arts, established in the states and territories by the Congress in 1862;

WHEREAS there is in connection with each of those colleges an agricultural experiment station to which the national government appropriates annually $30,000 for agricultural research, the results of which have been of untold value to agriculture and to the nation;

WHEREAS experiment stations for the mechanic arts and engineering, including in their scope research in physics, chemistry and other sciences, would be of equal value to the nation and would repay manyfold their cost, and

WHEREAS at the present time attention is directed to the need of preparation for every emergency, and this can best be accomplished by the advancement of science and the ability of our people to meet new conditions as they arise;

Resolved that the Committee of One Hundred on Scientific Research of the American Association for the Advancement of Science earnestly recommends the passage of the Senate Bill introduced by Mr. Newlands to establish experiment stations in engineering and in the other branches of the mechanic arts in connection with the colleges established by the Congress in the several states and territories, with an annual appropriation to each of $15,000 for conducting investigations and experiments and printing and distributing the results; and further

Resolved that the committee urges each of the ten thousand members of the American Association for the Advancement of Science to use all proper efforts to bring the importance of the measure before members of the congress and to the attention of the public.

NATIONAL PRODUCTIVITY IN SCIENCE

As claimed in the preamble to the resolutions of the Committee of One Hundred, science can only flourish in a democracy if it is supported by the people. A democratic system is favorable to mechanical inventions for there are large numbers who have a common school education, who see the need and have the opportunity to devise improvements in their tools. In the cotton gin and the harvester, the sewing machine and the typewriter, the telegraph and the telephone, in the development of the

DARWIN

steamboat and the railway, the automobile and the aeroplane, America has done more than its share. But as the machinery of civilization becomes more complicated, we can no longer depend on isolated invention, but must undertake investigations requiring long preliminary training and complex adjustments. To a certain extent the need is met by the industrial laboratories which by aid of the patent office now conduct elaborate investigations. But the ideal solution of the problem is to pay men for the value of their services or to employ men to do the work for which they are most competent, and this can best be accomplished if the people, as a whole, will make the investment and reap the profits. In no better way can this be done than by the support of the scientific bureaus of the government and the establishment of experiment stations in each state.

An aristrocratic social system has in the past been more favorable than a democracy to the production of men of exceptional performance in science. A selected class, possessing inherited ability and inherited wealth, can supply a few men far surpassing in ability the average man and can give them opportunity and appreciation. But we may hope that as soon as the value of research in pure and applied science, and, it may be added, of production in letters and the fine arts, are widely understood, a democracy may have a wider field from which to select men of special ability and will provide adequate opportunity and rewards.

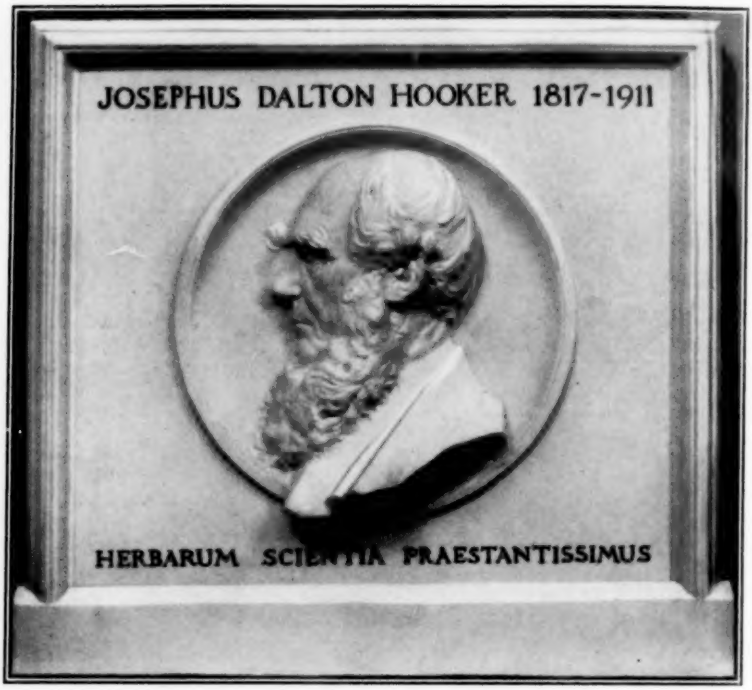
It would be interesting if we had a comparative study of the productivity

WALLACE

of different nations in science, which would determine how it has changed in quality, quantity and direction from period to period, and how far it has depended on natural ability and how far on social institutions. There is some basis to assume that the smaller European nations, Switzerland, Holland and the Scandinavian countries, have done remarkably well, that France has fallen behind Great Britain and Germany, that Great Britain has had the greatest number of men of exceptional performance, that Germany has produced the largest number of competent investigators and the best organization for research.

There are here reproduced photographs of four plaques which have been unveiled in Westminster Abbey, representing Darwin, Wallace, Hooker and Lister. They are fit representatives of the great men who gave distinction to Great Britain in the Victorian era. Of those men only Hooker held a scientific position, and he too is typical of the aristocratic system, for he inherited not only his ability, but also his wealth, his title and the directorship of the Kew Botanical Gardens from his father. Darwin is particularly notable as a representative of aristocratic and individualistic genius. He came from a family line manifesting great ability and having ample wealth; he married a wife from a similar line and transmitted to his children both ability and wealth. He filled no position but did his work while living as a country gentleman.

It is doubtful whether again we shall look on men like these. In Germany



HOOKER

also there have been distinguished leaders, but, on the whole, the contribution of that country to science has come from the large number of individuals engaged in scientific research at the universities. In the past the United States has not produced scientific leaders comparable to English scientific men of the nineteenth century or numbers of able investigators equal to those of Germany. But it may be that we have been gradually assuming a position in which we are contributing to the advancement of science on terms of equality with these nations. If the science with which the writer of this note is concerned may be taken as an example, it may be claimed that we produced in William James the greatest contemporary psychologist, and we appear to have more competent workers in psychology than any other nation. "Who's Who in Science" an English publication, selects for biographical sketches psychologists as follows from the different nations: United States, 95; Germany, 37; Great Britain, 30; Austria-Hungary, 13; France, 12; Italy, 12; Switzerland, 10; Russia, Holland and Norway, each 6.

In so far as the apparent superiority of America in psychology is due to the fact that it is a new science, the promise for the future in other directions is but emphasized. We are providing opportunity for research work in all the sciences, and we may be confident that the ability exists and only needs the chance to exhibit itself. The war will so cripple the resources in men and money of the great nations of Europe that peculiar responsibility is thrown upon us. We may also hope that the lesson of the war to us will be that the best preparation for the future is the development of our educational and scientific institutions.

LISTER

SCIENTIFIC ITEMS

WE record with regret the death of Sylvanus P. Thompson, the famous English physicist; of Carl Schwarzschild, director of the Astrophysical Observatory at Potsdam, and of E. Jungfleisch, professor of organic chemistry at the University of Paris.

THE late Lady Kelvin has bequeathed to Glasgow University £5,000 for promoting research and the teaching of physical science in connection with the chair of natural philosophy, long held by Lord Kelvin. The decorations and medals conferred on Lord Kelvin are also given to the university.—The British Chemical Society has decided to publish portraits of the three past presidents, Sir Henry Roscoe, Dr. Hugo Müller and Professor Raphael Meldola, who have died during the past year.

AT the annual spring meeting of the General Education Board $789,980 was appropriated for institutions and projects to which the organization contributes. The largest appropriation was for the medical department of Washington University at St. Louis, which received $250,000. This makes $1,000,000 given by the board to this institution toward a total of $1,500,000 for the purpose of placing the teaching of medicine, surgery and pediatrics on a full-time basis. Other appropriations were: Coker College, Hartsville, S. C., $50,-000; Colby College, Waterville, Me., $125,000; Rockford College, Rockford, Ill., $75,000; further prosecution of educational researches, $50,000; Spellman Seminary, Atlanta, Ga., $20,000; Hampton Institute, $25,000; Tuskegee

Institute, $25,000; Morehouse College, Atlanta, $5,000; Fisk University, Nashville, $5,000; Mayesville Industrial School, Mayesville, S. C., $1,000; equipment of normal schools for negroes in North Carolina, $4,050; equipment of county training schools for negroes, $10,000; support of professors of secondary education, $34,130; state agents for white rural schools, $40,800; state agents for negro schools, $34,500; educational research in New Hampshire, $5,500; farm demonstration work in Maine and New Hampshire, $8,500.

On the occasion of his seventieth birthday on March 16, 1916, Professor G. Mittag-Leffler and his wife made a joint last will and testament of peculiar significance in the domain of science. Extracts from this will have recently been published by Professor Mittag-Leffler in a pamphlet, so that the features of the document are now public property. By the terms of the will there is founded a mathematical institute to bear the name of the donors, which institute is to be housed in their villa at Djursholm, Stockholm. The institute is to be fully established at the death of the donors, and is to consist of the villa in question, the mathematical library of Professor Mittag-Leffler, and a fund for the encouragement of pure mathematics, particularly in the four Scandinavian countries, Sweden, Denmark, Finland and Norway, but more especially in Sweden. The library is to be open to all mathematicians. Certain financial assistance is to be given to those who show genuine aptitude for research and discovery in the domain of pure mathematics. There is also provided for the bestowal of medals and of prizes in the form of sets of the *Acta Mathematica*.

A second relief expedition is to be sent out from the American Museum of Natural History and the American Geographical Society in the hope of rescuing Donald B. MacMillan and the members of the Crocker Land Expedition sent out in 1913 by the American Museum of Natural History, the American Geographical Society and the University of Illinois. The party is believed to be several hundred miles northwest of northern Greenland. The first relief expedition is frozen in at Parker Snow Bay, 150 miles south of Etah. The second expedition will try to join forces with the first and then proceed to Etah. The steamship *Danmark* has been chartered for the trip, and the sum of $11,000 has already been pledged—$6,000 by the American Museum and its friends and $5,000 by the American Geographical Society.